Current Approach to the Diagnosis and Emergency Department Management of Appendicitis in Children

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Abstract: Concerns about radiation exposure have led to a decrease in the use of computed tomography in suspected appendicitis, with increased reliance on ultrasound. Children with suspected appendicitis should be risk stratified using a combination of clinical signs and symptoms, white blood cell count, and ultrasound in order to guide further evaluation and management. Magnetic resonance imaging is a promising imaging modality but remains costly. Ongoing research is evaluating the role of nonoperative management in children with confirmed appendicitis.

Key Words: abdominal pain, appendicitis, clinical decision rule, diagnostic testing, surgery

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TARGET AUDIENCE
This CME activity is intended for physicians who care for children with acute abdominal pain, including general pediatricians, emergency physicians, and surgeons.

LEARNING OBJECTIVES
After completion of this article, the reader should be able to:

1. Describe trends in diagnostic imaging for children with suspected appendicitis.
2. Integrate clinical presentation, laboratory studies, and ultrasound findings to assess a child’s risk of appendicitis and guide further workup.
3. Provide appropriate initial management for children with confirmed appendicitis in the emergency department.

Acute appendicitis remains a diagnostic challenge for pediatric acute care clinicians. In this article, we review the historical perspective and epidemiology of acute appendicitis in children. We will then outline a basic framework for the diagnostic approach to children with suspected appendicitis, which integrates clinical findings, laboratory studies, and imaging modalities.

HISTORICAL PERSPECTIVE
Appendicitis was first described in 1886, with prompt surgical management recommended as definitive treatment.1 Until the late 20th century, diagnosis was purely based on history and physical examination, with an acceptable negative appendectomy rate of 20% to 25%.2 The increase in utilization of computed tomography (CT) over the last 2 decades led to a steady decrease in the rate of negative appendectomies.2 More recently, the negative appendectomy rate in children approaches 4%, with higher rates in young children and female adolescents.3

Because of increasing recent concerns about radiation exposure in children, the rate of CT usage in the evaluation of appendicitis has decreased significantly with a balancing increase in ultrasound utilization. Reassuringly, this trend appears to have had no adverse effect on the rate of ED revisits, appendiceal perforation, or negative appendectomy rate.4 Recent progress in the evaluation of suspected appendicitis has focused on strategies that integrate clinical scores, the white blood cell count, and ultrasound findings to risk-stratify children and facilitate management decisions.

EPIDEMIOLOGY
The incidence of acute appendicitis in the United States is 11 per 10,000 people per year, with a lifetime risk of appendicitis between 5% and 10%.5 Appendicitis is most common in children 10 to 19 years of age and has a slight male predominance.6 It is also slightly more common in the summer months.5 Risk factors for perforation include longer duration of symptoms and younger age.6–8

DIFFERENTIAL DIAGNOSIS
The differential diagnosis of a child presenting with suspected appendicitis is broad and is summarized in Figure 1. Special consideration should be given to the female adolescent, who is at risk of ectopic pregnancy and ovarian pathology, and to the very young child, who is at increased risk of perforation.

HISTORY AND PHYSICAL EXAMINATION
The first symptom of appendicitis in a child is usually a complaint of periumbilical or generalized abdominal pain. Classically, but not always, over the course of hours, the pain worsens and migrates toward the right lower quadrant (RLQ). Low-grade fever, anorexia, nausea, and vomiting may be present, but the abdominal pain generally precedes these symptoms. The child may complain of pain with walking. The location of pain in appendicitis may vary, depending on the length and position of the appendix. Thus, clinicians should not eliminate appendicitis from consideration in children presenting with pain in the right upper quadrant, flank, groin, or suprapubic region. Similarly, the duration of the symptoms will affect the intensity of the symptoms and signs, making the diagnosis quite difficult in the early stages.

The physical examination should begin with a general assessment of the appearance and activity level of the child. An active child who is walking easily around the room is less likely to have appendicitis than the child who is laying quietly in bed resistant to movement. Key components of the examination include careful examination of the lung fields to evaluate for pneumonia and a genitourinary examination especially in males (testicular torsion, hernia) and amenorrheic pubescent girls (hematocolpos). In sexually active girls, a bimanual examination may be indicated to assess for cervical motion tenderness and adnexal tenderness or fullness. The abdominal examination should focus on the location...
of maximal tenderness, with the RLQ being most suggestive of appendicitis; many clinicians refer to the point of maximal tenderness relative to McBurney point, the position one third of the distance medially along a line drawn from the anterior superior iliac spine to the umbilicus. Examination of the abdomen should also attempt to identify signs of peritonitis such as rebound tenderness, guarding, and referred pain to the RLQ from palpation of the left lower abdomen (Rovsing sign). Unwillingness to jump or cough is also suggestive of peritoneal irritation. Bowel sounds will be hypoactive in advanced appendicitis. Right-lateral-wall tenderness on rectal examination can also be suggestive of appendicitis, but rectal examinations have become less routine in young children. Less specific findings in patients with an inflamed retrocecal appendix include an obturator sign (pain with internal rotation of the right hip) and psoas sign (pain with extension of the hip or flexion of the hip against resistance).

Table 1 summarizes the frequency of specific signs and symptoms in children with suspected appendicitis. It should be noted that many children present with atypical features; for example, in the cited study, 40% of children with confirmed appendicitis did not have anorexia, 30% did not have maximal tenderness in the RLQ, and 20% had pain duration of more than 48 hours. Almost 20% of children with confirmed appendicitis had report of diarrhea. In addition, a substantial number of children without appendicitis exhibited features such as RLQ tenderness, percutaneous tenderness, and guarding.

**LABORATORY EVALUATION**

A complete blood count with differential should be obtained for all children in whom appendicitis is suspected, as the WBC count and absolute neutrophil count (ANC) have been shown to be useful in predicting risk of appendicitis. Other laboratory tests, although not generally useful in predicting risk of appendicitis, may help to exclude alternate etiologies. A urine pregnancy test should be obtained for all postpubertal females. A normal urinalysis rules out new-onset diabetes and decreases the likelihood of urinary tract infection or nephrolithiasis. It is important to remember that many children with appendicitis will have "sympathetic," or sterile, pyuria with a few WBCs in the urine due to ureteral or bladder irritation. If the abdominal pain is more prominent in the right upper quadrant or if there is persistent vomiting, transaminases, serum bilirubin, and lipase may be indicated to evaluate for hepatobiliary pathology or pancreatitis. Serum electrolytes should be obtained in ill-appearing or very dehydrated patients. C-reactive protein, although possibly associated with increased risk of perforation and complicated clinical course, does not discriminate appendicitis from other causes of abdominal pain.

**CLINICAL SCORES**

Although history, physical examination, and laboratory findings are helpful in the evaluation of a patient with suspected appendicitis, no single finding sufficiently predicts a child’s risk. Thus, several clinical scores have been developed that combine historical and examination factors with WBC count to better risk stratify individuals with suspected appendicitis. The Kharbanda low-risk rule for appendicitis states that patients with an ANC of less than 6.75 × 10^9/L and either no maximal tenderness in the RLQ or maximal tenderness in the RLQ but no pain with walking, jumping, or coughing have a low risk of appendicitis. With a sensitivity of 98%, the rule was very effective in identifying children who were unlikely to have appendicitis and in whom imaging may be deferred while observing the patient for improvement or progression.

The original Alvarado score (also known by the mnemonic MANTRELS) was intended to direct adult patients to surgery, but does not have sufficient performance in children to determine the need for operative care. Similarly, Samuel proposed the Pediatric Appendicitis Score (PAS) to identify high-risk patients in need of surgery (Table 2). Subsequent studies indicated that
the PAS cannot be used for that purpose, but can be used for risk stratification to guide further evaluation.

Thus, the current preferred approach to suspected appendicitis is to use clinical scores or decision algorithms to risk stratify patients into those who may require further observation (low risk), those who would benefit from additional data through advanced imaging (medium risk), and those who need more urgent surgical consultation for advanced or possibly complicated appendicitis (high risk). Two recent publications have combined the clinical score with the results of ultrasound to further refine decision making.

### IMAGING

The most common imaging modalities in the emergency department evaluation of suspected appendicitis are CT and ultrasound. Computed tomography has superior test characteristics, but ultrasound is more commonly used as a first-line modality to limit radiation exposure in children. Plain films of the abdomen are not routinely indicated without concerns for obstruction or alternative diagnoses; occasionally, the plain film can reveal appendicoliths, urolithiasis, or significant constipation. On ultrasound, an inflamed appendix will generally appear as an enlarged, hyperemic, noncompressible tubular structure with or without an appendicolith or localized free fluid (Fig. 2). While the overall sensitivity has been cited at 88\%, with a specificity of 94\%, ultrasound is operator dependent, and sensitivity is as low as 35\% in institutions where ultrasound is used infrequently in the evaluation of suspected appendicitis. Sensitivity of ultrasound is highly dependent on the ability to visualize the appendix. When the appendix is visualized and able to be characterized as normal or abnormal, the sensitivity of ultrasound is close to 98\%. Unfortunately, ultrasound fails to visualize the appendix in nearly 50\% of cases. A nonvisualized appendix is more common in patients with high body mass index. In an ultrasound with a nonvisualized appendix, the presence of secondary signs, such as focal phlegmon, hyperechoic pericecal fat, or a moderate to large amount of free fluid should be considered highly suggestive of appendicitis. One recent retrospective study found that a nonvisualized appendix without secondary signs in a patient with WBC of less than 7.5 × 10^9/mL had a negative predictive value of 98.9\%. Importantly, the sensitivity and negative predictive value of ultrasound improve with duration of abdominal pain.

Computed tomography has a sensitivity of 94\% and a specificity of 95\% for the diagnosis of appendicitis in children (Fig. 3). If CT is performed, intravenous contrast alone is generally adequate. Enteral contrast could be considered if there is concurrent concern for bowel obstruction, abscess, or inflammatory bowel disease. Some institutions have developed reduced-dose CT scan protocols specifically for the diagnosis of appendicitis, which can further help limit radiation exposure in children.

Because of the aforementioned limitations of ultrasound and appropriate concerns about radiation exposure with CT, there has been increasing interest in the use of magnetic resonance imaging (MRI) in the diagnosis of appendicitis (Fig. 4). Magnetic resonance imaging appears to have excellent test characteristics but is limited by availability and cost and is not yet widely used as a routine diagnostic modality.

### APPROACH TO THE CHILD WITH A NONDIAGNOSTIC ULTRASOUND

The most challenging scenario is a patient who has moderate suspicion of appendicitis, but has a nondiagnostic ultrasound. Management of such a patient depends on risk tolerance of the clinical team and patient/family, the ability to have close outpatient follow-up, and the availability of advanced imaging modalities. A child who is overall well appearing, has improving symptoms or signs and a normal WBC count and differential, and can reliably return if symptoms worsen may be discharged home with careful counseling after an oral fluid challenge. Patients with more severe clinical symptoms, worsening symptoms or signs, or an elevated WBC count may be considered for CT scan, MRI scan, or...

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**TABLE 2. Calculation of the PAS and Alvarado Score\(^{16,17}\)**

<table>
<thead>
<tr>
<th>Finding</th>
<th>PAS</th>
<th>Alvarado</th>
</tr>
</thead>
<tbody>
<tr>
<td>RLQ tenderness to palpation</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>RLQ pain with hopping, coughing, or percussion (PAS) or rebound tenderness (Alvarado)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Anorexia</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Nausea and/or vomiting</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Migration of pain to RLQ</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fever ≥38°C (PAS) or &gt;37.3°C (Alvarado)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>WBCs ≥10,000/μL</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>≥75% neutrophils (PAS) or left shift (Alvarado)</td>
<td>1</td>
<td>1</td>
</tr>
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Adapted from Alvarado\(^{16}\) and from Samuel.\(^{17}\)

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**FIGURE 2. Ultrasound, tip appendicitis. Case courtesy of Dr Maulik S. Patel, Radiopaedia.org, rID: 13043.**
inpatient admission with serial abdominal examinations. Because patients with a high pretest probability of appendicitis and an equivocal or even negative ultrasound still have significant risk of appendicitis, these patients should be considered for advanced imaging such as CT or MRI. Serial ultrasounds have also been used successfully in patients with initially equivocal ultrasounds and persistent clinical concern for appendicitis. A basic approach to risk stratification and management is outlined in Figure 5.

**EARLY MANAGEMENT CONSIDERATIONS**

All children with suspected appendicitis should not be allowed to eat or drink. In the hemodynamically unstable or ill-appearing patient, fluid resuscitation, empiric broad-spectrum antibiotics, and emergency surgical consultation are crucial. For less critical patients, intravenous analgesics and antiemetics should be offered. It has been shown that use of opioids does not mask features important for diagnosis of appendicitis; thus, early pain management is encouraged. As ultrasound requires graded compression in the RLQ to displace bowel gas and visualize necessary structures, pain control is best offered prior to ultrasound.

Once appendicitis is confirmed, antibiotics should be given to all patients. While one prospective cohort study did not show a benefit of preoperative antibiotics in children with appendicitis, this study was limited by small numbers. The American Pediatric Surgical Association recommends that all children with appendicitis receive preoperative broad-spectrum antibiotics. Vital signs should be obtained frequently to monitor for evolving sepsis. Surgical consultation should be obtained, with transfer to an appropriate facility when necessary.

**ADDITIONAL MANAGEMENT CONSIDERATIONS**

**Urgent Versus Emergent Operative Care**

When surgical management is indicated, operative care should proceed in an urgent, but not necessarily emergent, manner. While overall duration of symptoms does predict perforation, recent studies have shown that taking a reasonable amount of time to perform an appropriate examination and to conduct serial examinations does not increase the risk of histopathologic perforation or postoperative wound infections. Given the routine use of preoperative antibiotics and current surgical techniques, early perforations have excellent outcomes.

**Operative Versus Nonoperative Management**

Children with perforated appendicitis may be admitted for intravenous antibiotics pending percutaneous and per-rectum drainage procedures and/or delayed appendectomy. While the majority of children with nonperforated appendicitis undergo urgent appendectomy, a growing body of research suggests that select children with uncomplicated appendicitis may be adequately treated nonoperatively with antibiotics. Rates of subsequent appendectomy were 20% to 40% in studies with 1-year follow-up, and the presence of an appendicolith has been shown to lead to an unacceptably high rate of relapse. A recent study suggested that involvement of the patient and/or family in the decision for operative or nonoperative management is a reasonable option that could lead to decreased morbidity and cost. Opportunities exist for future research to identify those
who are likely to succeed with medical management alone versus those who may benefit from early operative intervention.

FUTURE DIAGNOSTIC STRATEGIES

The optimal diagnostic approach to patients with suspected appendicitis is an active area of research. Refined management strategies will likely include electronic medical record–based decision support with age-adjusted and gender-adjusted risk stratification. Improvements in ultrasound technology and scanning techniques, as well as more standardized reporting, will aid clinicians in risk stratification. Use of point-of-care ultrasound may help streamline care for children with suspected appendicitis.48 Finally, while the WBC and ANC have been the main laboratory values used in the diagnosis of appendicitis in children, other biomarkers from both the serum and urine, identified through studies of the pathophysiology of the disease, are being investigated.49–55

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