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Acute Appendicitis in Pediatric Patients: An Evidence-Based Review

Abstract

Appendicitis is the most common condition in children requiring emergency abdominal surgery. Delayed or missed diagnosis in young children is common and is associated with increased rates of perforation. Although several scoring systems have been developed, there is still no consensus on clinical, laboratory, and imaging criteria for diagnosing appendicitis. This issue reviews key age-based historical and physical examination findings, as well as clinical scoring systems, that can help guide the workup of appendicitis in children. The existing literature is reviewed to provide guidance for the management of children with appendicitis, including recommendations for diagnostic studies, prophylactic antibiotics, pain medication, and surgical consultation.

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Case Presentations

An 11-year-old previously healthy boy presents to the ED on a busy Saturday evening. He has acute abdominal pain that started 18 hours ago as diffuse periumbilical abdominal pain. Within the last 3 hours or so, the pain migrated to the right lower quadrant and worsened in severity. The child says the bumps on the car ride to the hospital were painful, and hopping up and down makes the pain worse. He says it seems to be a bit better when he lies still and does not move. Oral ibuprofen has not really helped the pain. The patient has not eaten a meal all day and has vomited 3 times today. On presentation, he has a temperature of 38.3°C (101°F). He is fully immunized and does not have any upper respiratory symptoms. He has never had similar pain in the past and has no history of previous abdominal surgeries. He has a normal genitourinary examination. He has obvious discomfort with palpation of his abdomen with maximum tenderness in the right lower quadrant. He exhibits guarding and rebound tenderness. His mother asks you whether this could be appendicitis, and whether he will need surgery. You begin to think… Is this appendicitis? What else could it be? How will you definitively determine the diagnosis? What laboratory evaluation and imaging tests should you order? It is now 2:00 AM. If the patient definitely has appendicitis, does he need an emergent appendectomy or can it wait?

Your next patient is a 16-year-old girl with abdominal pain who is brought into the ED by her mother. When the girl arrived to the ED, her vital signs were age-appropriate except for tachycardia, with a heart rate of 115 beats/min. Initially, she had some mild pain in her lower abdomen that gradually got worse. What is your differential diagnosis? What history, physical examination findings, or diagnostic evaluations should you obtain?

Your last patient of the evening is a 4-year-old boy with abdominal pain who is brought into the ED by his parents. The parents report that the boy was at his baseline state of health until 2 days ago when he became more fatigued and did not want to play as much. Today, he has had poor oral intake and spiked a fever to 38.6°C (101.5°F). The patient has been moaning and seems to grab at his abdomen in pain. Again, the diagnosis of appendicitis comes to mind. Is the rate of perforated appendicitis higher in this age group? How do you get an accurate history and perform a physical examination if the child will not talk to you and cowers behind his father when you approach him?

Introduction

Abdominal pain is a common chief complaint for pediatric patients presenting to an emergency department (ED) and, most of the time, the etiology is self-limited and nonemergent. Nonetheless, acute appendicitis must be considered in the differential diagnosis of abdominal pain in the pediatric population because missed acute appendicitis can lead to morbidity and mortality as well as medicolegal consequences.

In children, acute appendicitis is the most common condition requiring emergency surgery, with > 75,000 children diagnosed annually in the United States.[1] The potential for morbidity and mortality from perforation of the appendix necessitates prompt diagnosis.[2] Although a variety of clinical scoring systems have been developed, there is still no consensus on clinical, laboratory, and imaging criteria for diagnosing appendicitis, which poses a dilemma for the emergency clinician.[3-5]

This issue of *Pediatric Emergency Medicine Practice* reviews the existing literature to help develop strategies for the diagnosis and management of appendicitis in the pediatric population.

Critical Appraisal of the Literature

A literature search was performed in PubMed using the search terms *appendicitis*, *abdominal pain*, *pediatrics*, *clinical scoring systems*, *ultrasound*, *diagnostic tests*, *radiation risk*, and *non-operative management*. An English language filter was applied, and articles were sorted by relevance. Several thousand articles were found, with over 1000 screened by title, then abstract. A total of 101 articles were chosen for inclusion.

There are many deficiencies inherent to the quality of the literature, including the lack of pediatric studies and more retrospective studies. According to standard evidence-level scales, the majority of evidence for pediatric appendicitis falls into the "weak" or "moderately strong" categories, and there are many single-center studies with limited enrollment. There is an article from the Effective Health Care Program on the "Diagnosis of Right Lower Quadrant Pain and Suspected Appendicitis" in the National Guidelines Clearinghouse.[6] Despite these studies, there is no clear consensus on the approach to the pediatric patient with abdominal pain.

Epidemiology and Pathophysiology

Epidemiology

Among the pediatric population, appendicitis is the most common condition requiring emergent abdominal surgery, and is diagnosed in 1% to 8% of children evaluated in the ED for abdominal pain.[7,8] A delay in diagnosis is common in young children and has been reported in as many as 57% of cases in children aged < 6 years.[9] This delay is likely related to the atypical presentation of appendicitis in this age group, the overlap of symptoms with many common childhood illnesses, the inability of these children to communicate, and challenges related to assessment of the abdomen.[10] Delayed diagnosis, in turn, correlates with increased rates of perforation.[11] The rate of perforation decreases to < 15% in adolescence.[10,12]

Although children with abdominal pain present year-round and diagnoses of appendicitis are made throughout the year, it has been noted that rates are higher from May through September.[13] The lifetime risk of developing acute appendicitis among boys and girls is 8.6% and 6.7%, respectively.[13] Appendicitis rates are higher for white patients compared to nonwhite patients.[13,14] A retrospective study of 9424 pediatric patients found that the rate of acute appendicitis was 5.1% in white children compared to 1.9% in black children.[14] Black and Hispanic children are more likely to present with perforated acute appendicitis, compared to white children.[15,16]

Pathophysiology

The appendix is a blind-ended tubular structure that arises from the posteromedial aspect of the cecum, proximal to the ileocecal valve. The average length of the appendix varies from neonates to adults, ranging from 4.5 mm to 9.5 mm.[17] The orientation of the appendix can be retrocecal, subcecal, preileal, retroileal, or in a pelvic site. This variability accounts for the range of clinical presentations of appendicitis.[18,19]

Appendicitis is a result of obstruction of the appendiceal lumen. Obstruction can occur secondary to stones, fecaliths, or other processes that inflame the lymphoid tissue. Intraluminal bacterial overgrowth follows appendiceal obstruction and leads to breakdown of the mucosal barrier, bacterial invasion of the appendiceal wall, inflammation, ischemia, and gangrene, eventually leading to perforation. Inflammation of the wall of the appendix causes peritonitis, which produces localized abdominal pain and tenderness as well as typical right lower quadrant tenderness, guarding, and rebound. Perforation is rare in the first 12 hours but is increasingly common thereafter (especially after 72 hours), and it leads to release of bacteria into the peritoneal cavity.[19-21]

The bacteria that cause appendicitis include the usual fecal flora. A 2014 retrospective study of 415 adult patients with peritoneal fluid or periappendiceal abscess culture-positive appendicitis found that the most common pathogens were *Escherichia coli* (66.7%), *Streptococcus* (14.7%), *Enterococcus* (7.7%), *Klebsiella* (6%), and *Pseudomonas* (5.8%).[22] Less commonly, enteric pathogens and parasites including adenovirus, rubeola (measles), *Actinomyces israelii*, *Enterobius vermicularis* (pinworm), and *Ascaris lumbricoides* (roundworm) may directly infect the appendix or cause localized appendiceal lymphoid hyperplasia with obstruction.[23]

Neoplasms of the appendix are rare, and found in 1% of appendectomy specimens. Carcinoid tumors are the most common, comprising > 50% of appendiceal neoplasms.[24] A retrospective study of 4747 pediatric appendectomies found the incidence of appendiceal carcinoid tumors to be 1 in 593 appendectomies (0.169%).[25] A carcinoid tumor is a neoplasm originating from neuroendocrine tissue found along the primitive gastrointestinal tract. Appendiceal carcinoid tumors rarely cause metastatic disease and are commonly an incidental finding at the time of appendectomy.[24-26] Carcinoid tumors cause appendicitis as a form of luminal obstruction, but this is uncommon, as they are most often located at the tip of the organ.[26] Goblet cell carcinoids (also called *adenocarcinoids*) arise from a pluripotent cell that differentiates into both mucinous and neuroendocrine cells. Goblet cell carcinoids are aggressive tumors and can recur locally or metastasize to the lungs, which is why complete removal of these tumors is recommended.[27]

Differential Diagnosis

If bilious vomiting is present along with abdominal pain in infants and younger children, malrotation with midgut volvulus must be considered. Intussusception should be considered in younger patients (typically aged ≤ 3 years) presenting with episodic abdominal pain. Diabetic ketoacidosis should always be considered in a child with abdominal pain, vomiting, and anorexia; and basilar pneumonia can also present with abdominal pain. The most common misdiagnoses of appendicitis are acute gastroenteritis and constipation. In a retrospective study, 26% of cases of missed appendicitis were initially diagnosed as gastroenteritis.[28]

In girls of childbearing age, pelvic pathology is common and is easily confused with appendicitis. For these patients, the differential must include gynecologic/obstetrical causes such as ovarian torsion or pelvic inflammatory disease, and a detailed sexual history and urine pregnancy test should be obtained. Pelvic ultrasonography should also be considered to rule out ovarian torsion if the history is suspicious. A pelvic examination may be necessary in adolescent girls who are at risk for sexually transmitted infections or pelvic inflammatory disease.

Postpubertal male patients should undergo a complete physical examination, including a genitourinary examination, to rule out testicular torsion or other genitourinary diagnoses.

For a list of causes of right lower quadrant pain, **see Table 1, page 4**.

Prehospital Care

Children with suspected appendicitis should receive nothing by mouth (NPO) until a definitive diagnosis is made. Hydration status should be assessed, and intravenous (IV) hydration initiated, if needed, as well as pain control. If a need for a pediatric surgeon is anticipated, transfer to a higher-level facility should be started.[9]

Emergency Department Evaluation

The clinical presentation of children with appendicitis varies from that of adults. In preverbal toddlers and preschoolers, a pain history is often impossible; a caregiver must communicate the history. Conclusions must be drawn from the caregiver's assumptions and descriptions of how the child has been feeding, sleeping, and voiding. The physical examination findings can help determine the location of pain.

In older children, abdominal pain is a nearly universal symptom of acute appendicitis. Pain classically begins as poorly defined midabdominal or periumbilical pain that migrates to the right lower quadrant over a period of hours to days. Unlike younger children who may not be able to accurately describe their pain, school-aged children can usually reliably describe their pain.

Table 1. Differential Diagnosis of Right Lower Quadrant Abdominal Pain

Gastrointestinal
- Appendicitis
- Appendiceal neoplasm
- Constipation
- Gastroenteritis
- Inflammatory bowel disease (Crohn disease or ulcerative colitis)
- Intussusception

- Meckel diverticulitis
- Mesenteric adenitis
- Omental torsion/infarct
- Pancreatitis
- Perforated ulcer
- Small-bowel obstruction
- Typhlitis

Gynecological
- Endometriosis
- Ovarian torsion
- Pelvic inflammatory disease

- Ruptured ovarian cyst
- Mittelschmerz

Obstetrical
- Ectopic pregnancy
- Intra-amniotic infection
- Labor
- Placental abruption

- Round ligament pain
- Severe pre-eclampsia and HELLP syndrome
- Uterine rupture

Genitourinary
- Hernia
- Nephritis
- Orchitis
- Testicular torsion

- Urinary tract infection
- Renal colic (stone, ureteropelvic junction obstruction)

Extra-abdominal causes
- Diabetic ketoacidosis
- Hemolytic uremic syndrome
- Henoch-Schönlein purpura
- Osteomyelitis of the hip

- Referred pain from pneumonia/pleuritis
- Septic arthritis of the hip
- Streptococcal pharyngitis

Abbreviation: HELLP, hemolysis, elevated liver enzymes, low platelet count.

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Age-Specific Considerations

Infants

Although the occurrence of appendicitis is much less likely in this age group, it is also more difficult to diagnose, and delayed diagnosis leads to perforation or bowel obstruction.[9,12,29] When the history is obtained from parents or caregivers, they should be asked about vomiting, diarrhea, irritability, fever, and decreased oral intake. Other features may include a palpable abdominal mass. Localized right lower quadrant pain is noted in < 50% of infants.[9]

Prepubertal Children

Appendicitis is rare in the prepubertal age group, with children aged ≤ 5 years accounting for < 5% of cases of appendicitis.[30] Adult studies show that abdominal pain almost always precedes vomiting. This typical sequence is less common in preschool-aged children, and they can present with vomiting that precedes abdominal pain. Children aged ≥ 2 years begin to acquire communication skills that permit earlier identification of appendicitis, but it is still very important to obtain a detailed history from the caregiver, as children in this age group are likely to give the same response to questions: either "yes" or "no." Distraction techniques may need to be used to reduce the anxiety a child may feel when a stranger examines a painful body part. Another way to assess for abdominal pain in this age group is to ask the child to hop up and down.

School-aged children are able to describe their symptoms better and are able to cooperate with the physical examination, making the history and physical examination much more clear. Children often present with classic symptoms of fever, nausea, vomiting, and anorexia. Periumbilical pain that migrated to the right lower quadrant is a common presenting symptom. Rebound, guarding, and peritoneal signs are concerning for ruptured appendicitis.[9]

Postpubertal Children

The incidence of appendicitis peaks during adolescence. During a private interview with the patient, a thorough social and sexual history should be obtained for all patients in this age group.

General Considerations

Fever is a common and nonspecific presenting symptom. In a prospective study, fever was the most suggestive sign of appendicitis in patients with undifferentiated abdominal pain. In a study of 246 patients with abdominal pain, both fever and vomiting were present in 18 of the 24 patients who were diagnosed with appendicitis compared to 49 of the 222 patients with other final diagnoses ($P < .01$; negative predictive value [NPV], 0.97; sensitivity, 0.75; specificity, 0.78; positive predictive value [PPV], 0.27).[31] Anorexia, nausea, vomiting, duration of abdominal pain,

and diarrhea can be associated with appendicitis but are also present in other conditions.[31] History of anorexia can be elicited by asking school-aged children if they are hungry, but in toddlers and preschoolers, anorexia may have to be inferred from a caregiver's history of food refusal or decreased appetite. Duration and progression of abdominal symptoms can be difficult to elicit in children but are critical to distinguish acute appendicitis from other potentially resolving causes of abdominal pain.

Physical Examination

The appendix may arise from different locations off of the cecum, which affects its projection in the abdomen (eg, retrocecum, pelvis, or extraperitoneum). As a result, patients may present with pain to different sites, based upon the location of the appendix. If the appendix is in the retrocecum, the pain may be absent in the abdominal area due to overlap by a distended cecum covering the appendix. Similarly, if the appendix lies in the pelvis, pain may be felt in this area rather than the abdomen.

Although physical examinations in younger children can be challenging at best, the history and physical examination (including repeat examinations, close follow-up, and observation) are key to making the diagnosis.[9] Younger children may have trouble cooperating with the examination, and they may not be able to answer questions clearly. It can be helpful to spend several minutes talking with a child to gain trust prior to beginning the examination. Painless components of the examination should be done first. Younger children may be more cooperative if allowed to sit on a caregiver's lap. Most school-aged children and adolescents can cooperate with an abdominal examination and state whether specific maneuvers are painful.

For children who do not want their abdomen examined, there are several distraction techniques that may be helpful. Most children will continue engaging in conversation if maneuvers are not painful. Telling the child that you are listening to his/her abdomen while using a stethoscope to palpate the 4 quadrants can provide a sense of where tenderness lies. In children who remain uncooperative despite all efforts of distraction, an examination while the child is asleep can be helpful.

Classic signs of appendicitis on physical examination are[32]:

- Local tenderness with some rigidity of the abdominal wall at or near McBurney point (the point over the right side of the abdomen that is one-third of the distance from the anterior superior iliac spine to the navel. This point corresponds roughly to the most common location of the base of the appendix where it is attached to the cecum.) Local tenderness with some rigidity of the abdominal wall at or near McBurney point

has a sensitivity of 86.3% and specificity of 94.5%.
- Rovsing sign (pain in the right lower quadrant on palpation of the left side) has a sensitivity of 35% and specificity of 90% (95% CI; 30%-40% and 87%-92%, respectively).
- Obturator sign (pain on internal rotation of the right hip) has a sensitivity of 34% and specificity of 90% (95% CI; 27%-41% and 86%-94%, respectively).
- Iliopsoas sign (pain on extension of the right hip, which is found in retrocecal appendicitis) has a sensitivity of 38% and specificity of 88% (95% CI, 31%-46% and 83%-91%, respectively).
- Rebound tenderness or pain with release of pressure after deep palpation of the abdomen has a sensitivity 86.9% and specificity of 78.6%.

To view a video that demonstrates evaluation for the classic signs of appendicitis, go to: www.youtube.com/watch?v=6LrL4ysi_AE.

Among studies on patients with suspected appendicitis, the Rovsing sign was the examination finding that was most suggestive of acute appendicitis.[32] The sensitivity of cough/hop tenderness was 74.6%, with a specificity of 84.8%. The sensitivity of guarding on physical examination was 69% , and the specificity was 67% (95% CI; 65%-73% and 64-69%, respectively).[32] In a prospective study, 88 of 123 (72%) patients with acute appendicitis presented with cough/hop pain compared to 68 of 726 (9%) patients without acute appendicitis (P < .001; odds ratio, 24.3 [95% CI, 15.3-38.7]); and 98 of 123 (80%) had right iliac fossa tenderness compared to 84 of 726 (12%) without acute appendicitis (P <.001; odds ratio, 19.4 [95% CI, 12.0-31.4]. These examination findings were the most suggestive of acute appendicitis.[33]

Diagnostic Studies

Scoring Systems

Since no single sign or symptom has been found to be sufficiently sensitive or specific for appendicitis in children, several clinical scoring systems have been developed to help guide clinical management. The pediatric appendicitis score (PAS) is a tool that uses history, physical examination, and laboratory results to categorize the risk of appendicitis in children with abdominal pain. The PAS is easy to apply, and separates patients into categories of low risk (PAS 1-2), intermediate risk (PAS 3-6), and high risk (PAS 7-10).[3] **(See Table 2, page 6.)** A prospective validation of the PAS in 849 children demonstrated an area under the curve (AUC) of 0.95. If a PAS score of ≤ 2 was used to discharge a patient home without further workup, only 2.4% of those patients discharged home would have had appendicitis. If a PAS score of ≥ 7 was used to take a patient to the operating room without further workup, only 4% of the patients

would have a negative appendectomy.[33]

The Alvarado scoring system assigns a point value to diagnostic criteria, with a maximum of 10 points. **(See Table 3)**. A patient with a score < 3 is considered to be at low risk for appendicitis. A score of 3 or 4 is considered to be "equivocal" for appendicitis. A score of 5 to 6 is considered to be "compatible with appendicitis," and observation, at least, is recommended. Patients with a score of ≥ 7 have "probable appendicitis," and the recommendation is to take these patients to the operating room.[4] In a prospective study, 588 patients were enrolled to evaluate the performance of the Alvarado and PAS scores. An Alvarado score > 7 yielded a sensitivity of 72% and specificity of 81% (95% CI; 66%-78% and 76%-84%, respectively), and an NPV of 85% and a PPV of 65% (95% CI; 81%-89% and 59%-72%, respectively).[34] In a systematic review of 26 prospective studies, likelihood ratios for the Alvarado score were 0.02 (< 4 points), 0.27 (4-6 points), 4.2 (≥ 7 points). Likelihood ratios for the PAS score were 0.13 (< 4 points), 0.70 (4-7 points), and 8.1 (≥ 8 points).[35] The PAS and Alvarado scoring systems revealed variable clinical accuracy and limited clinical utility on external validation, with a majority of patients receiving intermediate risk scores.

Recently, a new scoring calculator, the pediatric appendicitis risk calculator (pARC), was developed and validated. The calculator provides a patient-specific risk for appendicitis and has demonstrated good test performance, which, in recent studies, was superior to the PAS.[5,36] Variables included in the calculator are: sex, age, duration of pain, guarding, migration of pain to the right lower quadrant, maximal tenderness in the right lower quadrant, and absolute neutrophil count. The main benefit of the pARC over prior scores is that many patients are classified as being < 15% risk of or ≥ 85% risk of appendicitis; if the PAS score was used, more patients would fall into the intermediate risk category. However, the calculator requires sophisticated calculations, which hinders widespread adoption of the score. The pARC calculator is available at www.parcscore.org.[5]

An MDCalc online tool for the pediatric appendicitis score is available at: www.mdcalc.com/pediatric-appendicitis-score-pas

An MDCalc online tool for the Alvarado score is available at: www.mdcalc.com/alvarado-score-acute-appendicitis

An MDCalc online tool for the pediatric appendicitis risk calculator is available at: www.mdcalc.com/pediatric-appendicitis-risk-calculator-parc

Laboratory Studies

White Blood Cell Count

Although a white blood cell (WBC) count is frequently ordered in the workup of acute appendicitis, an elevated WBC count can be nonspecific. One study demonstrated that the WBC count and absolute neutrophil count (ANC) have a better diagnostic performance for suspected appendicitis in older children. The AUC for WBC count was 0.69 for patients aged < 5 years, 0.76 for patients aged 5 to 11 years, and 0.83 for patients aged 12 to 18 years (95% CI; 0.61 to 0.77, 0.73 to 0.79, and 0.81 to 0.86, respectively). The AUCs for ANC mirrored WBC performance.[37] In a meta-analysis, a WBC count < 9000/mcL and < 75% neutrophils had a negative likelihood ratio for appendicitis of 0.17 (95% CI, 0.07-0.42).[38] Several studies have demonstrated that the main utility of the WBC count can be to rule out appendicitis, with a low WBC count and ANC providing reassurance for the absence of appendicitis.[39-42]

C-Reactive Protein

C-reactive protein (CRP) is a nonspecific inflammatory marker, but the combination of the WBC

Table 2. Pediatric Appendicitis Score (PAS)[3]

Finding	Score
Anorexia	1
Nausea or vomiting	1
Migration of pain	1
Fever > 38°C (100.5 °F)	1
Pain with cough, percussion, or hopping	2
Right lower quadrant tenderness	2
White blood cell count > 10,000 cells/mcL	1
Neutrophils plus band forms > 7500 cells/mcL	1
Total = the pediatric appendicitis score	

Table 3. Alvarado Scoring System[4]

Finding	Score
Pain migration	1
Anorexia	1
Nausea/vomiting	1
Tenderness in right lower quadrant	2
Rebound abdominal pain	1
Elevation of temperature ≥ 37.3°C (99.1°F)	1
Leukocytosis with WBC count >10,000 cells/mcL	2
Differential WBC count with > 75% neutrophils	1
Total = the Alvarado score	

Abbreviation: WBC, white blood cell.

count and CRP increases the sensitivity of laboratory evaluation for acute appendicitis. The likelihood of appendicitis is increased if the WBC count is > 10,000 cells/mcL, CRP is > 3 mg/dL, and/or ANC is > 7000 cells/mcL.[9,32,39,43] Depending on the duration of symptoms, the WBC count and CRP can help differentiate patients with simple and perforated appendicitis.[42] CRP is less sensitive in the early stages of appendicitis compared to WBC count. CRP may be more accurate in detecting perforated appendicitis compared to WBC count, especially in patients with prolonged duration of pain.[38,44,45] A retrospective study of 128 patients found CT severity scores (using a 0-, 1-, or 2-point scale) based on CT-determined appendiceal diameters, appendiceal wall changes, caecal changes, periappendiceal inflammatory stranding, and phlegmon or abscess formation were highly correlated with CRP levels (r = 0.669, $P < .01$).[44] A meta-analysis found that, for patients with perforated appendicitis, the AUC was higher for CRP 0.87 compared to 0.85 for WBC count (95% CI; 0.74-1.01 and 0.81-0.89, respectively).[38] WBC count, ANC, and CRP are increased in patients with acute appendicitis, and, in combination with ultrasound and physical examination findings, can greatly increase their predictive value in the diagnosis of appendicitis.[43]

In summary, most patients with acute appendicitis will have an elevated WBC count, ANC, or CRP. Low (nonelevated) values for the WBC count and ANC offer some benefit for ruling out appendicitis.[9,19,32]

Urinalysis

A urinalysis may be useful in differentiating appendicitis from a urinary tract infection or nephrolithiasis. However, abnormal urinalysis findings can lead to misdiagnosis, as 7% to 25% of children with appendicitis have > 5 WBCs or RBCs per high-power field.[9]

Imaging Studies

Imaging studies are not warranted in most children with undifferentiated abdominal pain who are unlikely to have appendicitis, based on clinical examination and laboratory studies.[5,39] When warranted, imaging studies can be helpful to establish or exclude the diagnosis of appendicitis.

Ultrasound-first strategies published by the American College of Radiology and the American College of Emergency Physicians advocate for ultrasound as the initial diagnostic study in the workup of pediatric appendicitis to prevent ionizing radiation exposure in the pediatric population.[2,3] While computed tomography (CT) scans may have higher diagnostic yield, their use is not without risk. CT-related radiation exposure has been shown to increase cancer risk. X-rays are not routinely useful in the diagnosis of acute appendicitis, but recognition of an appendicolith may provide radiographic evidence of appendicitis.[46] Uncommonly, basilar pneumonia in children may present with abdominal pain.[47,48] However, with a classic presentation of appendicitis, children can be taken directly to the operating room without further imaging studies, per a surgeon's discretion.[33,49,50]

Ultrasound

Ultrasound has gained acceptance as the initial imaging study for patients with suspected appendicitis. Graded compression is the ultrasound technique most commonly used in the diagnosis of appendicitis.[51] However, the addition of posterior manual compression or positional scanning (scanning in the flank and pelvis region in addition to right lower quadrant) may improve visualization.[52,53] In pediatric patients, the overall sensitivity and specificity of ultrasound were 88% and 94%, respectively (95% CI; 86-90% and 92%-95%, respectively).[54]

The diagnosis of acute appendicitis can be largely excluded by ultrasound if the entire appendix is visualized and no secondary signs are seen. However, caution should be exercised in obtaining an ultrasound too early in the disease course (eg, with < 12 hours of symptoms), as it is associated with false-negative studies. Visualization rates vary from 22% to 98%.[52-54] Factors that affect variability include the skill of the sonographer and the child's body habitus. In an observational study of 263 children aged 4 to 17 years with suspected appendicitis, ultrasound was inaccurate in 101 examinations; inaccurate examinations were significantly associated with high body mass index (BMI ≥ 85th percentile, primarily false-negative studies).[55] ED point-of-care ultrasound (POCUS) can be useful to rule in appendicitis, but if clinical suspicion is high, a negative ED POCUS is not sufficient to rule appendicitis out.[32]

Ultrasound findings associated with appendicitis include: a noncompressible appendix, appendix wall diameter > 2 mm, overall appendiceal diameter > 6 mm, local right lower quadrant tenderness during ultrasound examination, and presence of appendicolith.[51,56-58] **(See Figure 1, page 8.)** Secondary signs associated with acute appendicitis include: free fluid in the right lower quadrant, echogenic edematous mesenteric fat stranding, appendiceal wall hyperemia, abnormal lymph nodes, abnormal adjacent bowel, and bowel wall edema.[59-61]

Several quality improvement studies demonstrated that, after the implementation of a standardized radiology report that included details about secondary signs of appendicitis, there was a decrease in CT use, decreased admission for observation in patients with suspected appendicitis and a nondiagnostic ultrasound, and decreased annual imaging costs.[62-64]

The rate of nonvisualized appendix ultrasound is reported to be 50%,[65] and there are differences in the literature on how these patients should be managed.

Surgical consultation is useful with nondiagnostic imaging. Next steps include observation for serial abdominal examinations, CT scan, or magnetic resonance imaging (MRI).[43,59,63] However, an equivocal ultrasound (ie, appendix incompletely visualized or nonvisualized) without secondary signs of acute appendicitis coupled with a nonelevated WBC count suggests that the patient probably does not have appendicitis. In a retrospective cohort study of 845 patients undergoing ultrasound for suspected appendicitis, the NPV of a nonvisualized appendix without primary or secondary signs of appendicitis (WBC count ≤ 9000/mcL and polymorphonuclear leukocyte differential ≤ 65%) was 95.0 (95% CI, 89.5-100).[43]

Computed Tomography

CT is generally available and is not operator-dependent. Additionally, CT can be useful in establishing an alternative diagnosis.[66] In pediatric patients, the sensitivity and specificity of CT for the diagnosis of pediatric appendicitis is 94% and 95%, respectively (95% CI; 92%-97% and 94%-97%, respectively).[54] CT findings of acute appendicitis include a fluid-filled tubular structure > 6 mm in diameter with periappendiceal inflammation.[54,66,67] CT scans with IV contrast alone are sufficient, as observational studies show that oral or rectal contrast does not improve the test performance over IV contrast alone.[68,69] A prospective study demonstrated that the sensitivity of ultrasound for appendicitis improved with longer duration of abdominal pain, whereas CT demonstrated high sensitivity regardless of pain duration.[70] Importantly, CT scans are associated with ionizing radiation, which can increase an individual's lifetime cancer risk. One retrospective study reported that a radiation-induced solid cancer is projected to result from every 300 to 390 abdomen/pelvis CT scans in girls aged < 15 years.[71]

Magnetic Resonance Imaging

MRI with or without contrast may be a suitable alternative to CT when ultrasound results are not diagnostic in children. MRI is not operator-dependent and does not expose children to ionizing radiation.[72,73] Several meta-analyses reported the diagnostic accuracy of MRI for appendicitis in children, with a pooled sensitivity of 96% and a pooled specificity of 96% (95% CI; 95%-97% and 94%-98%, respectively).[73-75] Studies demonstrate that a combination of ultrasound and MRI is feasible and comparable to CT, without affecting the negative appendectomy rate or perforation rate.[76,77] Like all diagnostic imaging modalities, MRI is not always definitive, and further study is needed.[72,73]

Limitations of MRI for the evaluation of appendicitis in the pediatric population include limited availability at certain facilities, the length of time it takes to complete the study, and the potential need for sedation in young children.[72] A 2017 retrospective study described the possible toxic effects of gadolinium, which include nephrogenic systemic fibrosis and intracranial deposition; these toxic effects may limit its use. More information about the effects of the contrast on children is needed before it can be recommended for widespread use.[78]

Selection of Imaging Study

There are limited data comparing the total costs of diagnosing and treating children with suspected appendicitis. A 2018 prospective study reported a 5.2% lower cost per case for sites that preferentially utilized ultrasound in the diagnosis of acute appendicitis compared to sites that primarily used CT.[79] Imaging rates vary due to clinical practice guidelines, clinician preferences, and imaging availability.[79,80] A recent analysis stratified patients into low-,

Figure 1. Ultrasound Images of Acute Appendicitis in a Child

A noncompressible, inflamed appendix is shown in (A) a cross-sectional view (7.5 MHz) and (B) a longitudinal section (7.5 MHz). Mural lamination of the swollen appendix is maintained in the early stages of acute appendicitis. In (C), an appendicolith (arrow) with acoustic shadowing is demonstrated (5 MHz).

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medium-, and high-risk categories for acute appendicitis followed by the staged utilization of ultrasound/CT, and it found a further 16% reduction in costs, without changes in patient outcomes.[81]

Treatment

Initial stabilization of patients with acute appendicitis includes pain control, keeping the patient NPO, and IV hydration. IV ondansetron (0.15 mg/kg/dose every 8 hours or as needed, max dose 8 mg) or a similar antiemetic agent can be given for nausea/vomiting associated with appendicitis.

Early analgesia is recommended. There was no increase in missed appendicitis or in negative appendectomies after analgesia with IV morphine (0.05 mg/kg, max dose 10 mg).[82,83] A recent retrospective trial conducted in Canadian pediatric EDs demonstrated that children with suspected appendicitis typically receive inadequate pain control. Out of 619 children with suspected appendicitis (88.4% with an appendectomy), 61% of patients received analgesia, with 42.8% receiving IV morphine. The median initial dose of morphine was 0.06 mg/kg, and the median time from triage to initial dose of analgesia was 196 minutes. Forty-three percent of patients received their initial dose of analgesia after surgical consultation, and 43.7% of patients received their initial dose of analgesia after an ultrasound was performed.[84]

Typically, surgical treatment is indicated for acute appendicitis. In patients with acute appendicitis, antibiotics are usually given preoperatively to decrease the risk of abscess formation and wound infection. Based on guidelines published by the Surgical Infection Society and the Infectious Diseases Society of America, the first-line antibiotic choice is ceftriaxone 50 to 75 mg/kg/dose IV once daily (max 2000 mg/dose) plus metronidazole 10 mg/kg/dose IV every 8 hours (max 500 mg/dose). If the patient is severely allergic to beta-lactam medications, the recommendation is to give ciprofloxacin 10 mg/kg/dose IV every 12 hours, (max dose 500 mg/dose) plus metronidazole 10 mg/kg/dose IV every 8 hours (max 500 mg/dose) or an aminoglycoside-based regimen.[85] Alternative antibiotic regimens include an aminoglycoside-based regimen (gentamicin 2.5 mg/kg/dose IV every 8 hours), a beta lactam/beta-lactamase-inhibitor combination (piperacillin/tazobactam 100 mg piperacillin/kg/dose IV every 6 to 8 hours [max 16,000 mg piperacillin/day]); or a carbapenem-based regimen (ertapenem 15 mg/kg/dose IV every 12 hours [max 500 mg/dose]).

In the past, acute appendicitis has been considered to be a surgical emergency that requires prompt appendectomy to avoid perforation and other complications. Recent studies suggest that adverse outcomes are not increased in children who receive timely administration of antibiotics and undergo appendectomy < 24 hours after diagnosis.[86,87] A 2017 prospective study demonstrated that time delays to appendectomy up to 12 hours from initial ED evaluation did not increase the odds of perforation.[88]

Nonoperative management for acute appendicitis may be feasible. However, the failure rate is higher compared to appendectomy.[89] See the "Nonoperative Management" section on page 11 for more information.

Special Populations

Appendicitis in Children Aged < 5 Years
The diagnosis of acute appendicitis in preschool-aged children remains a challenge. Most of these children present with complications (perforation, abscess formation, and peritonitis). Delay in diagnosis has been attributed to nonspecific presentations, overlap of symptoms with common childhood illnesses, inability of the child to communicate, and a challenging abdominal examination. The misdiagnosis rate ranges from 28% to 70% in children aged 2 to 12 years and approaches 100% in children aged < 2 years.[10,37] Rates of perforated appendicitis range from 20% to 53% in preadolescent children. A retrospective study examining children aged 3 to 12 years found that nausea, right lower quadrant tenderness, inability to walk, and elevated WBC and neutrophil counts were sensitive indicators of acute appendicitis in preadolescent children. When peritoneal signs are present, they substantially increase the likelihood of appendicitis.

Appendicitis in Pregnant Patients
Acute appendicitis is the most common surgical condition in pregnancy. Appendicitis occurs in about 1 in 1500 pregnancies and is most common in the second trimester. A mildly elevated WBC count is common in pregnancy, so it may not be a clear indicator of appendicitis.[90] The majority of pregnant women present with right lower quadrant abdominal pain.[90] However, as the uterus grows in size, the appendix migrates in the cephalad direction, and by the third trimester of pregnancy, pain may be located in the mid or upper right quadrant of the abdomen.[90,91]

The initial diagnostic imaging study of choice for pregnant patients is ultrasonography, although nonvisualization of the appendix is more common during pregnancy.[92] MRI would be the second-line imaging study, as it avoids ionizing radiation.[93,94] Treatment for appendicitis during pregnancy is appendectomy. Management with antibiotics alone is not recommended because it is associated with treatment failure. Delaying appendectomy is associated with increased rates of perforation.[95,96] The risk of fetal loss increases if the appendix perforates.[97]

9

Clinical Pathway for the Diagnosis of Appendicitis in Pediatric Patients

Patient presents with suspected appendicitis based on history and physical examination:
- Obtain laboratory tests **(Class II)**
- Assess using the PAS or pARC

Low risk:
- Minimal abdominal tenderness
- PAS: < 3
- pARC: < 5%

↓

Discharge home with clear return criteria within 24 hours

← NO

---

pARC 5%-15%

↓

Observation period

↓

Are the symptoms persistent?

YES →

Moderate risk:
- Some findings of appendicitis
- PAS: 3-6
- pARC: 16%-84%

↓

Obtain appendix ultrasound **(Class II)**

High risk:
- Classic findings of appendicitis
- PAS: ≥ 7
- pARC: ≥ 85%

↓

Obtain prompt surgical consultation **(Class II)**

From "Obtain appendix ultrasound":

Appendix completely visualized, without evidence of appendicitis (no secondary signs)

↓

Treat symptomatically and/or consider other diagnoses; consider repeat ultrasound, further imaging, observation if early or high pretest probability

---

Equivocal ultrasound

↓

Consider admission for observation **(Class III) or** Perform CT or MRI **(Class I)**

Evidence of appendicitis visualized on ultrasound

↓

Administer IV antibiotics and obtain surgical consultation **(Class I)**

From "Perform CT or MRI":

Negative CT or MRI or alternative diagnosis

↓

Treat symptomatically or treat alternative diagnosis

CT or MRI indeterminate and/or persistent symptoms

↓

Admit for observation with surgical consultation **(Class III)**

Evidence of appendicitis on CT or MRI

↓

Administer IV antibiotics and obtain surgical consultation **(Class I)**

Abbreviations: CT, computed tomography; IV, intravenous; MRI, magnetic resonance imaging; pARC, pediatric appendicitis risk calculator; PAS, pediatric appendicitis score.

Class of Evidence Definitions

Each action in the clinical pathways section of *Pediatric Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

Controversies and Cutting Edge

New Scoring Systems

There are several scoring systems available to help guide clinical management in the workup and diagnosis of acute appendicitis. The PAS and modified Alvarado score are well known; however, in validation studies, these scoring systems had limited clinical utility.[33-35] Recently, the pARC score has been shown to predict the risk of appendicitis with high discrimination (AUC 0.85).[5] Use of the pARC score requires sophisticated calculations that require the use of a calculator. Further research is required to determine how best to integrate the use of clinical scoring systems, diagnostic imaging, and/or serial abdominal examinations into the workup of pediatric appendicitis.

Nonoperative Management

Appendectomy for early appendicitis is the treatment of choice. However, there has been emerging evidence in the literature regarding nonoperative treatment of pediatric appendicitis. Nonoperative treatment may be an option in select children with early, uncomplicated appendicitis. Specifically, it may be safe for children aged ≥ 6 years who can describe their symptoms and have features of early appendicitis. These features include abdominal pain < 48 hours, WBC count ≤ 18,000 cells/mcL, normal CRP, no appendicolith present on imaging, appendix diameter ≤ 1.1 cm on imaging, and no preoperative concern for rupture, based on clinical findings.

A meta-analysis evaluated 5 prospective trials: 1 randomized trial and 4 prospective controlled trials in which nonoperative treatment was performed based on parent preference. Nonoperative treatment of appendicitis was successful in 91% of patients in the first month after presentation. By 1 year, 73% of patients had not undergone appendectomy and the recurrent appendicitis rate was documented at 22%.[98] In a meta-analysis of 10 studies with a total of 413 children undergoing nonoperative treatment, initial treatment was effective in 97% of patients at reported follow-up (ranging from 8 weeks-4 years), and the appendicitis recurrence rate was 14%. There was significant variation in antibiotic protocols, but they typically included 1 to 2 days of parenteral broad-spectrum antibiotics (eg, piperacillin-tazobactam, ceftriaxone and metronidazole, or ciprofloxacin and metronidazole) until resolution of symptoms and normalization of WBC count occurred, followed by oral antibiotics to complete a total of 10 days of antibiotics.[99] A retrospective study of insurance databases documented initial nonoperative treatment in 4000 children. Forty-six percent subsequently had an appendectomy and 14% had perforated appendicitis. During a 1-year follow-up period, nonoperative management was associated with significantly more advanced imaging and hospitalizations for appendicitis-related complications.[89] Longer-term clinical outcomes in large randomized trials are needed to inform decision-making. The APPY trial will be the first multicenter randomized trial comparing nonoperative treatment to appendectomy for acute uncomplicated appendicitis in children.[99,100]

In summary, nonoperative management may be an option in certain populations, but the risk of recurrence, need for diagnostic imaging to confirm the diagnosis, and exposure to broad-spectrum antibiotics must be considered.[101]

Disposition

Most children with the diagnosis of acute appendicitis should be admitted, and will need fluid resuscitation, IV antibiotics targeting enteric aerobes and anaerobes, and analgesia. Conversely, if a definitive diagnosis has not been established, the decision to admit for observation versus discharge with close follow-up should be made in conjunction with the surgical team and parental agreement. The child can also be observed in the ED for a brief period of time prior to more extensive testing. Patients who are discharged home should receive specific criteria for when to return to the ED.[9]

Summary

Appendicitis remains a common surgical emergency in the pediatric population. When acute appendicitis is suspected, there are several clinical scoring systems that can help guide clinical management. However, these scoring systems vary in specificity and sensitivity for accurately assessing the risk of appendicitis in individual patients. Ultrasound is the recommended first-line imaging modality in patients with suspected appendicitis, as it does not expose children to ionizing radiation. The rates of nondiagnostic appendix ultrasounds are around 50%, which presents a dilemma for ED clinicians. How these patients should be managed is controversial. Low-risk patients with indeterminate ultrasounds can be safely discharged home if close follow-up is ensured. Other patients may undergo a CT scan or be admitted to the hospital with surgery consult and serial abdominal examinations. ED management of children who are diagnosed with acute appendicitis should focus on pain control, IV hydration, administration of antibiotics, and consultation with a pediatric surgeon. A standardized approach to the child with suspected appendicitis would decrease resource utilization and healthcare costs. Nonoperative treatment may be an option in select children with early, uncomplicated appendicitis, but longer-term clinical outcomes from large randomized controlled trials are needed to inform decision-making.

Low-risk patients who are unlikely to have appendicitis should be discharged home without imaging.[65]

Case Conclusions

You sent a CBC and CRP for the 11-year-old boy with abdominal pain and vomiting. The WBC count and CRP were both elevated. An appendix ultrasound showed a dilated, noncompressible appendix with mesenteric fat stranding and appendiceal wall hyperemia, and you diagnosed the boy with appendicitis. The on-call pediatric surgeon was contacted and asked that you start antibiotics and admit the patient for appendectomy in the morning.

During a private interview with the 16-year-old girl, she confided that she had been having unprotected sexual intercourse. You sent STI testing and a urine pregnancy test. The urine pregnancy test came back positive, and the patient's abdominal pain continued to worsen during her time in the ED. A pelvic ultrasound confirmed the diagnosis of ectopic pregnancy, and ob/gynecology was appropriately consulted.

You were able to coax the 4-year-old boy out from his hiding place with a toy. While the patient was sitting in his father's lap and being distracted by the nurse blowing bubbles, you examined the boy's abdomen. It was soft with good bowel sounds present, there was no guarding, and the patient did not seem to have pain with palpation of his abdomen. Upon further questioning, you learned that the patient had been sick with upper respiratory infection symptoms for the past week and the fever started today. The patient had a congested cough several times while you were in the exam room. You ordered a chest x-ray and diagnosed a right-sided basilar pneumonia.

Time- and Cost-Effective Strategies

- Workup of patients with suspected appendicitis should be standardized, with a thorough history,

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Risk Management Pitfalls in the Management of Appendicitis in Pediatric Patients (Continued on page 13)

navigation: (Continued on page 13)

1. **"I saw this patient in the ED 2 days ago. He presented with 2 hours of vague abdominal pain, and his exam was not consistent with acute appendicitis. I can't believe he is back today with a perforated appendix."**
Early appendicitis can present with vague abdominal pain with a broad differential diagnosis. Therefore, it can be easy to miss early appendicitis. If a patient presents to the ED with < 24 hours of abdominal pain or the diagnosis is equivocal, close follow-up with a primary care provider or ED follow-up should be ensured if the patient's symptoms persist.

2. **"The caregiver of the 3-year-old patient with a fever did not provide any history of abdominal pain. I just found out that the boy has a perforated appendix."**
The diagnosis of acute appendicitis in preschool-aged children remains a challenge. Most of these children present with complications (perforation, abscess formation, and peritonitis). Delay in diagnosis has been attributed to nonspecific presentations, overlap of symptoms with common childhood illnesses, an inability of the child to communicate, and a difficult abdominal examination. Acute appendicitis should be considered in the nonverbal child with abdominal pain.

3. **"This patient had an ultrasound yesterday that didn't show appendicitis. He came back today with increasing abdominal pain, fever, and an ultrasound that shows a noncompressible, dilated appendix."**
Patients with an equivocal ultrasound or nonvisualized appendix on ultrasound should be either hospitalized for serial abdominal examinations and possible repeat ultrasound or have close outpatient follow-up arranged (within 24 hours). Shared decision-making between emergency clinicians and guardians should be utilized to make decisions for individual patients.

4. **"The 16-year-old girl who came in yesterday with abdominal pain had a completely visualized normal appendix on ultrasound. She came back in again today complaining of abdominal pain."**
There is a broad differential diagnosis for female patients who present with abdominal pain. Pregnancy and ovarian pathology must always be considered in female patients of childbearing age.

5. **"This child was diagnosed with acute appendicitis 10 hours ago. I don't understand why his clinical status deteriorated."**
Prolonged time to antibiotics after diagnosis of appendicitis is associated with increased risk of complications, including appendiceal perforation. However, there have been studies showing that appendectomy within 24 hours of diagnosis is not associated with increased risks of complications.

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physical examination, and laboratory evaluation. The use of standardized radiology reports that include details about secondary signs of appendicitis can decrease CT use, provide guidance for clinical management, and reduce imaging costs.

- Clinical decision rules can reduce variation in care and limit the use of diagnostic imaging.
- Patients who are found to be at low risk for appendicitis can be discharged home without an ultrasound with a reliable family, clear return criteria, and outpatient follow-up ensured.
  Risk Management Caveat: Be sure that all patients with nondiagnostic appendix ultrasounds have close follow-up (within 24 hours) if discharged home. Early appendicitis can present with vague complaints and families should be instructed about "red flag" symptoms associated with appendicitis and when to return to the ED.

Patients with persistent abdominal pain should be admitted for observation or have a CT scan to evaluate the appendix.
Risk Management Caveat: For patients with unreliable follow-up, persistent abdominal pain, or moderate risk scores, observation, serial examinations, diagnostic imaging, and consultation with surgery should be considered.

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such

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Risk Management Pitfalls in the Management of Appendicitis in Pediatric Patients (Continued from page 12)

6. **"When the patient presented to the ED yesterday, I decided to discharge him home without any laboratory evaluations because I didn't think they were necessary. He came back today and was diagnosed with appendicitis."**
   A CBC can be useful in patients with suspected appendicitis. A WBC count > 10,000 cells/mcL and an ANC > 7000 cells/mcL are suggestive of acute appendicitis in the appropriate clinical context. Clinical decision rules utilize WBC count and ANC to predict the risk of appendicitis and can provide emergency clinicians with guidance on clinical management.

7. **"The 7-year-old boy complaining of abdominal pain did not have significant abdominal tenderness when I examined him 2 hours ago. He represented to the ED and another provider documented an abnormal genitourinary exam and a diagnosis of testicular torsion confirmed by ultrasound."**
   Testicular pathology (eg, obstructed inguinal hernia or testicular torsion) can present as abdominal pain and should be considered in all male patients presenting with abdominal pain. Patients may be hesitant to disclose testicular pain. A genitourinary examination should be performed on all male patients who present to the ED with abdominal pain.

8. **"This 3-year-old boy seemed to have abdominal pain on exam, but he had a normal appendix ultrasound. He re-presented to the ED 2 days later with a large right-sided basilar pneumonia."**
   The preverbal child can be difficult to examine in the ED. Even though it is true that children aged < 5 years with appendicitis often present with a perforated appendix, other diagnoses are much more common in this age group and should be considered. Failing to consider a broad differential may result in missed pathology.

9. **"I decided to withhold morphine from my 8-year-old patient with suspected appendicitis. I didn't want to miss a diagnosis because I administered an analgesic."**
   Early analgesia is recommended. There is no increase in missed appendicitis or in negative appendectomies after analgesia. Adequate pain control for patients with suspected appendicitis in the ED is imperative.

10. **"I ordered an abdomen/pelvis CT to evaluate a 5-year-old girl with suspected appendicitis, but the radiologist told me that was an inappropriate initial diagnostic imaging study."**
    CT scans expose children to ionizing radiation, which increases lifetime cancer risk. Ultrasound-first strategies have been published by the American College of Radiology and the American College of Emergency Physicians, which recommend ultrasound as the initial imaging study for the evaluation of acute appendicitis in children.

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as the type of study and the number of patients in the study is included in bold type following the references, where available. The most informative references cited in this paper, as determined by the authors, are noted by an asterisk (*) next to the number of the reference.

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CME Questions

1. **Regarding pediatric appendicitis, which of the following statements is TRUE?**
   a. Appendicitis rates are higher for nonwhite patients compared to white patients.
   b. The lifetime risk of developing appendicitis is higher for females compared to males.
   c. Rates of appendicitis are higher in the months of November, December, and January compared to other times of the year.
   d. Acute appendicitis is the most common condition requiring surgery.

2. **A 16-year-old girl presents with 12 hours of right-sided abdominal pain. Which of the following laboratory tests is absolutely essential?**
   a. C-reactive protein (CRP)
   b. Urine pregnancy test
   c. Comprehensive metabolic panel
   d. Urinalysis

3. **A 4-year-old boy presents with abdominal pain. What is the best way to evaluate this child for appendicitis?**
   a. Ask the child direct and detailed questions.
   b. Perform the physical examination with the caregiver out of the room.
   c. Skip the physical examination and go straight to laboratory studies because the examination is so unreliable in this age group.
   d. Use distraction techniques to evaluate the child for pain, rebound tenderness, and guarding, in addition to obtaining a detailed history from the child's caregiver.

4. **Regarding clinical scoring systems for the diagnosis and management of appendicitis, which of the following statements is TRUE?**
   a. The pediatric appendicitis score (PAS) has 100% sensitivity and 100% specificity for the diagnosis of appendicitis in children.
   b. The PAS and pediatric appendicitis risk calculator (pARC) scores utilize components of the history, physical examination findings, and laboratory results to help guide clinical management in children with suspected appendicitis.
   c. The pARC score is a simple calculation that is readily available in any setting.
   d. When using the pARC score compared to the PAS score, there are more children categorized as being at intermediate risk for appendicitis.

5. **Regarding laboratory studies in patients with suspected appendicitis, which of the following statements is TRUE?**
   a. White blood cell (WBC) count and absolute neutrophil count (ANC) have better diagnostic performance in younger children compared to adolescents.
   b. WBC count, ANC, and CRP can be increased in patients with acute appendicitis, and, in combination with ultrasound and physical examination findings, can greatly increase their predictive value in the diagnosis of appendicitis.
   c. Elevated CRP is a specific finding of appendicitis.
   d. WBC count may be more sensitive at detecting perforated appendicitis compared to CRP.

6. **What should be the FIRST radiographic test performed in a child with suspected appendicitis?**
   a. Computed tomography (CT) with contrast
   b. Abdominal x-ray
   c. Ultrasound
   d. Magnetic resonance imaging (MRI) with or without contrast

7. **In the workup of appendicitis, which of the following is a benefit of CT scan compared to ultrasound?**
   a. CT scan is generally available and not operator-dependent.
   b. Ultrasound exposes children to radiation, but CT does not.
   c. The sensitivity of CT for appendicitis improves with longer duration of abdominal pain, and ultrasound demonstrated high sensitivity regardless of pain duration.
   d. Ultrasound requires children to be sedated to complete the study, while CT does not.

8. **An 8-year-old girl has been diagnosed with acute appendicitis. What intervention(s) are the best next steps in her management?**
   a. Give the patient oral antibiotics and discharge her home.
   b. Admit the patient to the hospital for observation.
   c. Administer pain control, consult with a member of the surgery team, keep the patient NPO, and administer IV antibiotics.
   d. Perform a urinalysis to exclude concurrent urinary tract infection.

9. **A 10-year-old boy has been diagnosed with perforated appendicitis. He has no medication allergies. Which antibiotic(s) should you administer?**
   a. Gentamicin IV
   b. Ciprofloxacin IV and metronidazole IV
   c. Meropenem IV
   d. Ceftriaxone IV and metronidazole IV

10. **Regarding nonoperative management of appendicitis, which of the following statements is TRUE?**
    a. Nonoperative management for appendicitis may be feasible. However, the failure rate is higher compared to appendectomy, and large randomized controlled trials are needed to inform decision-making.
    b. Nonoperative management may be safe for younger children who cannot describe their symptoms.
    c. Nonoperative treatment may be appropriate for children in whom appendiceal rupture is suspected.
    d. Nonoperative management and appendectomy are equally effective treatment options for early appendicitis.

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DIAGNOSTIC POINT-OF-CARE ULTRASOUND: An Update on Assessment Techniques in the Pediatric Trauma Patient

AUTHORS
Joshua Guttman, MD, FRCPC, FAAEM
Bret P. Nelson, MD, RDMS, FACEP

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Emergency ultrasound is performed at the point of care to answer focused clinical questions in a rapid manner. Over the last 20 years, the use of this technique has grown rapidly. The use of emergency ultrasound in the pediatric setting is increasing due to the lack of ionizing radiation with these studies, as compared to computed tomography. Utilizing diagnostic point-of-care ultrasound for pediatric trauma patients in the emergency department can allow clinicians to arrive at a diagnosis at the bedside rather than sending the patient out of the department for another study. This supplement focuses on some of the common indications for diagnostic ultrasound that may be useful in the setting of trauma, as found in the pediatric literature or extrapolated from adult literature where pediatric evidence is scarce.

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Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents.

Goals: Upon completion of this activity, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

CME Objectives: Upon completion of this activity, you should be able to: (1) obtain essential components of the history and physical examination to accurately diagnose appendicitis in the pediatric population; (2) discuss clinical decision rules that can help guide clinical management; (3) identify appropriate diagnostic laboratory evaluations and imaging studies for the workup of patients with acute appendicitis; and (4) determine appropriate treatment options for appendicitis (operative vs nonoperative management).

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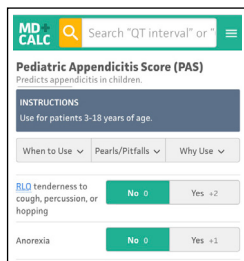
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Pediatric Appendicitis Score (PAS)

The pediatric appendicitis score predicts the likelihood of a diagnosis of appendicitis in pediatric patients with abdominal pain.

Points & Pearls

- The pediatric appendicitis score (PAS) predicts the likelihood of appendicitis in patients aged 3 to 18 years who present with abdominal pain with a duration of ≤ 4 days.
- The PAS stratifies patients as low risk, high risk, or equivocal for appendicitis.
- The score includes findings from the history, physical examination, and laboratory testing.
- The PAS should not be used in patients who have known gastrointestinal disease, are pregnant, or have had abdominal surgery previously.

Advice

Patients who are identified as not low risk (eg, equivocal or high risk) for appendicitis by the PAS should receive nothing by mouth, and the next steps should include administration of intravenous fluids and analgesia, ordering imaging, and/or surgical consultation.

Critical Action

Patients in the low risk group according to the PAS do not have *no* risk for appendicitis. Emergency clinicians should use clinical discretion to determine if imaging or surgical consultation would help with diagnosis for these patients.

Evidence Appraisal

The PAS was developed in 2002 by Dr. Madan Samuel in a prospective cohort study of 1170 patients aged 4 to 15 years who presented with abdominal pain. Clinical history, physical examination, and laboratory data for these patients were analyzed to identify 8 variables that showed statistical significance for acute appendicitis. A 10-point scoring system was created using these variables.

The PAS has been validated in multiple prospective studies. Bhatt et al (2009) studied 246 children aged 4 to 18 years and found a sensitivity of 97.6%, with a negative predictive value of 97.7%, at a cutoff PAS of ≤ 4 points. When a PAS of ≥ 8 points was used to determine that appendectomy was needed, the specificity was 95.1% and the positive predictive value was 85.2%. In this cohort, 41% of computed tomography scans would have been avoided using the PAS. Goldman et al (2008) evaluated the PAS in 849 children aged 1 to 17 years; the area under the receiver operating characteristic curve was 0.95, although the study used more conservative cutoffs of ≤ 2 points and ≥ 7 points.

Schneider et al (2007) evaluated both the PAS and the Alvarado score and found that they had similar sensitivity and specificity, but concluded that neither score was sufficient to be relied on as the only method to determine whether appendectomy is needed. Shah et al (2016) developed a diagnostic algorithm and used it prospectively in 840 patients, 267 of whom were ultimately diagnosed with appendicitis. The algorithm was found to have a sensitivity of 98.6% and specificity of 94.4%, with a decrease in utilization of computed tomography from 75.4% to 24.2%.

Use the Calculator Now

Click here to access the PAS on MDCalc.

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Madan Samuel, MD
Click here to read more about Dr. Samuel.

References

Original/Primary Reference

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  DOI: https://doi.org/10.1053/jpsu.2002.32893

Validation References

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Why to Use

The PAS has been validated in multicenter studies and may be as good as clinician gestalt at identifying patients who are at low risk for appendicitis versus patients with appendicitis.

When to Use

Use the PAS for children and adolescents who present with acute abdominal pain in whom appendicitis is suspected, especially if the pain is localized to the right lower quadrant.

Next Steps

Low Risk PAS (< 4 points)
- Patients with low-risk PAS scores have a low likelihood of acute appendicitis. Imaging is usually not warranted in these patients.
- There is a higher negative predictive value (95%) with the absence of right lower quadrant pain, the absence of pain with walking, jumping, or coughing, and an ANC of < 6750 cells/mcL.
- Other causes of acute abdominal pain should be considered in patients with low-risk scores.

Equivocal PAS (4-6 points)
- Imaging can be helpful in this group of patients. Ultrasound or MRI are preferred for pediatric patients.
- Surgical consultation is warranted for patients with equivocal scores.

High Risk PAS (≥ 7 points)
- Surgical consultation is warranted for patients with high-risk scores.
- Imaging may be pursued for this group of patients, but patients should undergo only ultrasound prior to a surgical consultation.

Abbreviations: ANC, absolute neutrophil count; MRI, magnetic resonance imaging; PAS, pediatric appendicitis score.

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Alvarado Score for Acute Appendicitis

The Alvarado score for acute appendicitis predicts the likelihood of a diagnosis of appendicitis.

Points & Pearls

- The Alvarado score is more accurate at the extremes than for equivocal scores, so it is unclear whether the score is better than clinical gestalt.
- Symptoms of appendicitis may overlap with other diseases (ie, higher scores can be found in patients with nonappendiceal inflammatory conditions, such as diverticulitis or acute pelvic inflammatory disease). Therefore, it is important to consider the whole clinical picture in making the diagnosis of appendicitis.
- There are several modifications of the Alvarado score in use; these modifications may be appropriate in specific settings, such as for children, pregnant patients, or in low-resource facilities with limited or no laboratory testing capability, but the original score remains the best studied and validated in a general population.

Critical Actions

Clinicians should use clinical judgment in nonclassic presentations of appendicitis.

Evidence Appraisal

The Alvarado score was initially described in 1986 by Dr. Alfredo Alvarado in a retrospective study at a single center in Philadelphia. For 305 patients aged 4 to 80 years, 8 predictive factors were identified to stratify the risk of acute appendicitis. Increasing scores were found to correlate with increasing risk for appendicitis, as determined by final surgical pathology.

In 2007, McKay et al studied a retrospective cohort of 150 patients (aged ≥ 7 years) presenting with abdominal pain, with the aim of stratifying risk specifically for the use of computed tomography

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Why to Use

Acute appendicitis is a common surgical emergency in the United States. Diagnostic accuracy for appendicitis is increased with the use of CT scanning; however, there are risks and disadvantages associated with CT scans, including radiation exposure, contrast-related complications, and cost. The Alvarado score is a well-established and widely used clinical decision tool that may help reduce the need for CT scans when diagnosing appendicitis.

When to Use

The Alvarado score can be used for patients with suspected acute appendicitis (typically, patients presenting with right lower quadrant pain).

Next Steps

- Cutoffs differ by study, but one validated stratification assigns the highest risk to Alvarado scores ≥ 9 in men and a score of 10 in women; the lowest-risk scores were ≤ 1 in men and ≤ 2 in women (Coleman 2018).
- In patients whose score indicates high risk, treatment without obtaining CT imaging should be considered. Alternative diagnoses should be considered in patients whose score indicates low risk. In patients with equivocal scores, CT scanning should be considered to help clarify the diagnosis.

Abbreviation: CT, computed tomography.

(CT) scanning for diagnosis. They found 35.6% sensitivity for appendicitis based on equivocal Alvarado scores (defined as scores of 4-6) compared with 90.4% sensitivity based on CT scan in this group. They concluded that patients with equivocal scores would benefit from CT scanning.

Similarly, Coleman et al (2018) conducted a retrospective review in which the Alvarado score was applied to a cohort of 492 patients (median age, 33 years), and found that 20% of the patients

were in either the high-risk group (defined as scores ≥ 9 in men or a score of 10 in women) or the low-risk group (scores ≤ 1 in men and ≤ 2 in women). These patients spent a cumulative total of > 170 hours awaiting CT scanning that was ultimately unnecessary. The authors found that scores of 0 or 1 had 0% incidence of acute appendicitis and that 100% of men with a score ≥ 9 and 100% of women with a score of 10 had acute appendicitis confirmed on surgical pathology.

Pogorelić et al (2015) prospectively studied 311 pediatric patients and applied both the Alvarado score and the pediatric appendicitis score (Samuel 2002). Receiver operating characteristic analysis showed similar accuracy between the scores, with area under the receiver operating characteristics of 0.74 (95% confidence interval, 0.66-0.82) for the Alvarado score and 0.73 (95% confidence interval, 0.65-0.81) for the pediatric appendicitis score. The authors concluded that the scores may be useful in emergency settings, but neither score is superior to the clinical gestalt of a pediatric surgeon.

Use the Calculator Now

Click here to access the Alvarado score on MDCalc.

Calculator Creator

Alfredo Alvarado, MD
Click here to read more about Dr. Alvarado.

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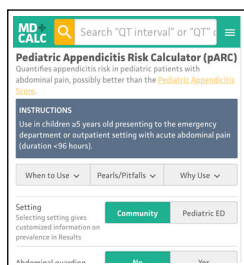
Pediatric Appendicitis Risk Calculator (pARC)

The pediatric appendicitis risk calculator quantifies appendicitis risk in pediatric patients with abdominal pain, possibly better than the pediatric appendicitis score.

Click the thumbnail above to access the calculator.

Points & Pearls

- The patients in the pediatric appendicitis risk calculator (pARC) study were aged 5 to 18 years. Appendicitis is relatively rare in children aged < 5 years and when it does occur in that age group, it is more likely to present with atypical features not captured by the pARC.
- Cases of appendicitis among patients in the lowest-risk groups (< 5% or 5%-14% risk as determined by the pARC) were missed only 0.4% of the time in each group. The sensitivity of the pARC was 100% in patients with < 5% risk of appendicitis; the sensitivity was 97.2% in patients determined to have a 5% to 14% risk.
- The specificity of the pARC was 99.7% for patients determined to be at highest risk of appendicitis (> 85% risk) and the specificity was 97.5% for patients in the high-intermediate risk group (75%-84%).

Critical Actions

Critically ill patients or patients with emergent "surgical abdomens" (rigidity, visible ecchymosis or hematoma, etc) should not be considered for delayed surgical consultation or imaging. These patients will likely benefit from early consultation with pediatric surgeons and from imaging, if they are able to be transported to radiology.

Evidence Appraisal

The pARC formula was derived from a dataset of 2423 patients with an interquartile age range of 8 to 14 years. Candidate predictors with > 10% missing data were not included. Patients with certain comorbid conditions were also excluded (Kharbanda 2018).

While absolute neutrophil count (ANC) was used in the pARC formula, ANC values were missing for

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Why to Use

The pARC may help determine the need for advanced imaging such as formal ultrasound or CT scan. It can identify low-risk patients who can be observed in the ED or discharged from the ED with follow-up or return precautions. In a validation study, the pARC formula performed better than the PAS by placing fewer patients into equivocal risk categories, making the pARC potentially more useful than the PAS for aiding clinical decision-making.

When to Use

Use the pARC in children aged ≥ 5 years who present to the ED or outpatient setting with acute abdominal pain with a duration < 96 hours. Patients with the following conditions were excluded from the pARC study:

- Pregnancy
- Previous abdominal surgery
- Inflammatory bowel disease
- Chronic pancreatitis
- Sickle cell anemia
- Cystic fibrosis
- Any medical condition affecting the ability to obtain an accurate history
- History of abdominal trauma within the previous 7 days

Next Steps

Patients determined by the pARC to be at low risk for appendicitis can be considered candidates for safe discharge or observation in the ED without advanced imaging such as ultrasound or CT scan, based on the discretion of the emergency clinician and the comfort level of the patient's family.

Given the specificity of the pARC, patients who are classified as high or high-intermediate risk for appendicitis may not need advanced imaging. In the high-risk group, 1.2% of appendectomy specimens were negative for appendicitis on pathology analysis and in the high-intermediate risk group, 2.6% of the specimens were negative.

Abbreviations: CT, computed tomography; ED, emergency department; pARC, pediatric appendicitis risk calculator; PAS, pediatric appendicitis score.

216 (9%) of the patients in the derivation data set. For patients missing the ANC value, it was imputed as ANC = $(-0.8783 + 1.1008 \times \sqrt{WBC})^2$. For patients missing both ANC and white blood cell count values, the ANC value was imputed as 7×10^3/mcL, which was the mean ANC value in the derivation cohort. The proportion of missing values was less than the 10% cutoff point chosen by the study authors; however, imputation of missing values has the potential to introduce bias into the equation.

An independent validation study was conducted at different centers and demonstrated the ability of the pARC to outperform the pediatric appendicitis score (Cotton 2019). This study demonstrated a superior area under the receiver operating characteristic curve with nonoverlapping 95% confidence intervals as compared to the pediatric appendicitis score.

Use the Calculator Now

Click here to access the pARC rule on MDCalc.

Calculator Creator

Click here to read more about Dr. Kharbanda.

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