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Evidence-Based Management Of Suspected Appendicitis In The Emergency Department

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CME Objectives

Upon completion of this article, you should be able to:

1. Recognize the symptoms, signs, and laboratory findings for appendicitis.
2. Select the most appropriate imaging techniques and therapeutic options for patients with presumptive appendicitis.
3. Describe the most common medicolegal pitfalls associated with appendicitis.

Prior to beginning activity, see "Physician CME Information" on page 32.

Abstract

Appendicitis is the most common cause of acute abdominal pain requiring surgical treatment in persons under 50 years of age, with a peak incidence in the second and third decades. Women have a greater risk of misdiagnosis and a higher negative appendectomy rate. Atypical presentations of appendicitis are commonly misdiagnosed, resulting in increased morbidity, mortality, and potential litigation. The variability of presentation relates to the varied anatomical location and the visceral innervation of the appendix. Patients presenting with possible appendicitis should be risk stratified based on history, physical examination, and laboratory data. An elevated white blood cell (WBC) count alone (> 10,000 cells/mm^3) offers poor diagnostic utility; however, combining WBC count > 10 and C-reactive protein (CRP) level > 8 achieves notable predictive power in the diagnosis of acute appendicitis. Imaging studies play a vital role in diagnosis, particularly in equivocal presentations.

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Case Presentations

About halfway through your evening shift, you notice a woman and a young boy walking through the halls, being escorted by the triage nurse to one of the ED bays. The young boy is crouched over and walking slowly. On history, you elicit that this is a 7-year-old boy who has had 2 days of mild periumbilical pain that is now localized to the RLQ. He wants to eat and is hungry, but his mother brought him in because he vomited twice after coming home from school, had diarrhea, and has been crying all night. Two of his friends were recently diagnosed with viral gastroenteritis. On physical examination, he is afebrile with a pulse of 114. Coughing produces notable grimacing, and he has tenderness to deep palpation in most areas of his abdomen, but is it unclear if it is more prominent in the RLQ. His abdomen is not rigid, and he lacks a psoas or obturator sign but has mild rebound tenderness. You think he may have appendicitis, but viral gastroenteritis and lower lobe pneumonia are also on your differential. You don't think he needs to go to the operating room immediately but wonder if you have enough information to call the on-call surgeon for evaluation. Is there any utility to poking this young man for labs or ordering imaging? Are there any appendicitis scoring systems for pediatrics that may help you with decision-making?

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Available Online At No Charge To Subscribers

EM Practice Guidelines Update: "Pharyngitis: Current Guidelines For Emergency Clinicians"
www.ebmedicine.net/Pharyngitis

As you ponder these questions, a 62-year-old female presents with an "upset stomach," suprapubic discomfort, and dysuria over the last 12 hours. She said this feels similar to UTIs that she's had in the past, so she took a ciprofloxacin this morning with no relief. She is afebrile with stable vital signs and a soft abdomen with mild suprapubic tenderness with trace rebound, no guarding. Labs returned with WBCs of 10 and RBC of 5, with negative nitrates, bacteria, and squamous cells. She states that she still feels "uncomfortable in her stomach" but otherwise is without complaints. What is your next step?

Next, a 25-year-old male presents with periumbilical/midepigastric-area pain for 6 hours, now with RLQ pain and vomiting, a temperature of 39.3°C (102.3°F), and RLQ pain. At the request of the surgical resident, you obtain a CT with IV and PO contrast, which is resulted at 11 PM and demonstrates nonperforated appendicitis with no abscess present. The resident is notified and states, "Just give him antibiotics and admit to surgery, and we'll add him on first thing in the morning." Being the patient advocate that you are, you then call the attending, who was a bit upset that you woke her up late at night. She reiterates what the consult resident said. Since you can't do the surgery yourself, you give the patient IV cefoxitin, thoroughly document the conversations you just had, and admit the patient, all the while hoping that the patient doesn't perforate on the surgical ward overnight.

Introduction

Appendicitis is the most common cause of acute abdominal pain requiring surgical treatment in both children and adults under the age of 50, with peak incidence occurring in the second and third decades of life.[1] Appendicitis is the most common nonobstetrical abdominal emergency in pregnant women, occurring most often in the second trimester.[2,3,4] Although acute appendicitis presenting in a typical fashion may be diagnosed with relative ease, these typical presentations are the exception and not the rule. Atypical presentations are commonly misdiagnosed, resulting in increased morbidity, mortality, and potential litigation. For these reasons, it is vital to be informed of the most recent literature concerning this common diagnosis. In this issue of *Emergency Medicine Practice,* the most current findings in regard to the diagnosis of appendicitis in the emergency department (ED) will be discussed, with particular attention towards elucidating the elements of history, physical examination, and laboratory testing that will most benefit the emergency clinician faced with the dilemma of diagnosing possible appendicitis. Further emphasis will be placed on the optimal radiologic examination that can be offered to a patient, with emphasis on minimizing risks associated with this testing.

Critical Appraisal Of The Literature

An extensive literature search through the PubMed database was performed for *acute appendicitis,* limited to meta-analyses, practice guidelines, reviews, and randomized controlled trials in English with a publication date in the last 20 years. A total of 506 publications were found, and each was browsed for relevance to the current topic. In addition to the selection of articles from this initial search, relevant citations from these selected articles were also acquired and examined via PubMed. Furthermore, an extensive search of the Cochrane Database and the National Guidelines Clearinghouse was performed. The Cochrane Database search resulted in 2 pertinent publications involving the importance of antibiotics administration in preventing postoperative wound infection and the value of analgesia in acute abdominal pain. The National Guidelines Clearinghouse search demonstrated guidelines from the American College of Radiology (ACR), American College of Emergency Physicians (ACEP), and the Infectious Diseases Society of America (IDSA). These guidelines are summarized in **Table 1**.

Epidemiology

Approximately 250,000 cases of appendicitis occur annually in the United States.[5] Males have an overall higher rate of appendicitis, with a male-to-female ratio of approximately 1.4:1, with a lifetime risk of appendicitis of 8.6% for males and 6.7% for females.[1,6] Despite these statistics, it has been reported that the lifetime risk of undergoing an appendectomy is 12% for males and 23.1% for females. This discrepancy is best explained by an elevated negative appendectomy rate in females due to decreased diagnostic accuracy as a result of gender-specific pelvic pathology that mimics appendicitis.[6]

Appendicitis is the second most common cause of malpractice claims in children aged 6 to 17, the third most common in patients over the age of 18, and the leading cause of malpractice litigation in cases involving abdominal pain. Missed appendicitis cases comprise 10% of all closed malpractice claims.[3,7] Appendicitis is relatively uncommon in patients under the age of 5 or above the age of 50; however, in these patient populations, appendicitis frequently presents atypically and is associated with increased incidence of delayed diagnosis, appendiceal rupture, morbidity, and mortality.[8,9] As a result, although the overall mortality rate with appropriate treatment is less than 1%, in the elderly it has been reported to be between 5% and 15%.[11,12]

Although not demonstrated definitively, like many other disease entities, it has been postulated that appendicitis has a polygenetic inheritance as well as a significant environmental contribution.[13] A genetic component to appendicitis has been implied through both a small case-controlled trial as well as

Table 1. Practice Guidelines Relevant To The Diagnosis And Treatment Of Appendicitis In The Emergency Department

Practice Guideline	Methodology	Findings
ACR Appropriateness Criteria®, Right Lower Quadrant Pain — Suspected Appendicitis	• Consensus of expert panel using a systematic review • Evidence tables summarizing randomized and/or prospective trials and meta-analyses • Modified Delphi technique used to create recommendations when existing evidence was insufficient	In suspected appendicitis, CT with IV and PO or PR contrast is the examination of first choice in all patients except: • Pregnant women: ultrasound first followed by MRI, if needed • Children: ultrasound first, followed by CT • If CT necessary in children, consider limited RLQ study
ACEP Clinical Policy: Critical Issues in the Evaluation and Management of Emergency Department Patients With Suspected Appendicitis	• Consensus of expert panel based on systematic review • Evidence tables of all classes of trials with greatest weight given to randomized and/or prospective trials and meta-analyses	In suspected appendicitis: • History and physical examination are acceptable to risk stratify patients • Abdominal CT without IV/PO contrast is acceptable, although IV/PO contrast may increase sensitivity • In children, ultrasound should be used to diagnose but not to exclude appendicitis
Diagnosis and Management of Complicated Intra-abdominal Infection in Adults and Children: Guidelines by the Surgical Infection Society and the Infectious Diseases Society of America	Consensus of expert panel based on randomized clinical trials and meta-analyses	Antibiotics should be administered as soon as an intra-abdominal infection is identified and selection should be directed by severity of illness and patient's background (eg, community- vs nosocomial-acquired) **(See Table 4, page 18)**

Abbreviations: ACEP, American College of Emergency Physicians; ACR, American College of Radiology; CT, computed tomography; IV, intravenous; MRI, magnetic resonance imaging; PO, by mouth; PR, per rectum; RLQ, right lower quadrant.

a retrospective twin study from Australia.[13,14]

Risk factors for appendicitis include male gender, Caucasian ethnicity, and presentation in the summer months. In addition, young age is a risk factor for appendicitis, with 69% of cases occurring in persons less than 30 years old and the highest incidence occurring in 10- to 14-year-old males and 15- to 19-year-old females.[6] A few studies have found a link between decreased dietary fiber and increased appendectomy rates, but they were disadvantaged by either small study sizes or recall bias.[1,15,16] Lastly, some studies have suggested an association between tobacco use and appendicitis.[17-19]

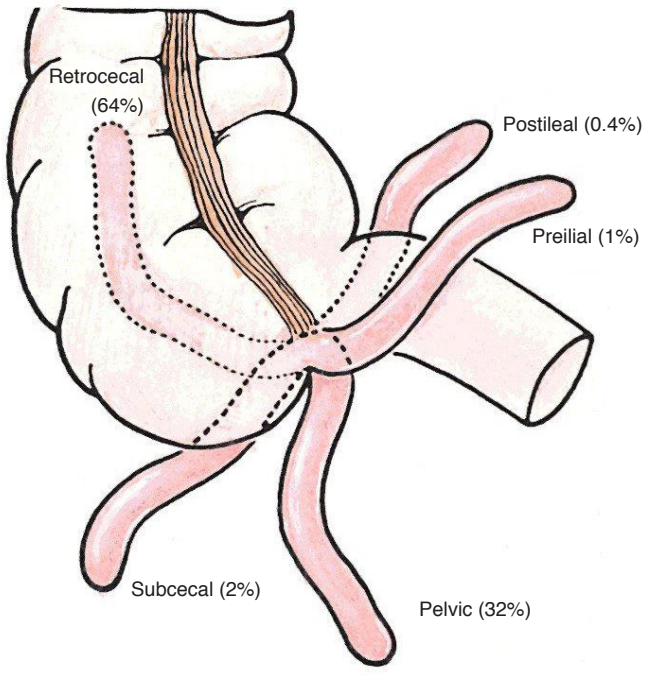
Pathophysiology

The difficultly in clinical diagnosis of appendicitis is directly related to variations in the location of the appendix in both genders as well as its native location adjacent to pelvic organs in females, which may have pathologic conditions that mimic symptoms of appendicitis. The appendix originates from the cecum, approximately 3 cm below the ileocecal valve. It has an average length of 8 to 10 cm, although it may be more than 25 cm long.[1,20,21] Structure begets symptoms, and this is true of the appendix, whose variable position in the peritoneal cavity leads to a wide range of symptoms and signs in appendicitis and resultant increased difficulty in clinical diagnosis.[1,11] The frequency that the appendix is found in various locations is as follows: retrocecal, 64.3%; pelvic, 32%; subcecal, 2.3%; preileal, 1%; postileal, 0.4%.[1,11] The easiest way to remember the varied locations is to realize that the base of the appendix is often located at McBurney's point and pain or tenderness due to appendicitis can extend in a clockwise direction around this point, like spokes on a wheel.[1] **(See Figure 1.)** Of note, appendicitis may present with left lower quadrant (LLQ) pain in patients with very long appendices or those with situs inversus, both of which—although rare—are always to be kept in the differential in the appropriate clinical scenario.[1] In addition, there have been reports of up to 11% of retrocecal appendices extending into the retroperitoneum, which may present with right flank pain.[22]

Classically, the essence of appendiceal pathophysiology is rooted in luminal obstruction, which subsequently leads to bacterial proliferation and intraluminal invasion. This process has been demonstrated both experimentally as well as histologically.[1,11,23,24] The causes of luminal obstruction vary and include fecaliths, fecal stasis, lymphoid hyperplasia (primary or secondary due to an infectious source, especially in the young), foreign bodies (such as vegetable matter and inspissated barium; even an ingested tongue ring has been reported), tumors (both primary and metastatic), and intestinal worms/parasites (ascarids in particular).[1,11,22,23] Despite this classic explanation, luminal obstruction can only be identified in approximately 50% of nonperforated acute appendicitis pathologic specimens. This is a direct contrast to perforated appendicitis, in which the large majority of cases demonstrate an obstruction.[1] It is important to note that obstruction and inflammation of the appendix may be limited to the distal tip of the appendix, leading to a condition called "tip appendicitis." This finding is often missed on radiologist interpretations of computed tomography (CT) scans and is a contributing element to the false-negative rate of CT in appendicitis.[25]

The traditional teaching is that acute appendicitis is a progressive disease. This progressive pathophysiology can best be understood by dividing it into 5 stages[26]: (1) appendiceal obstruction and initial distension; (2) stimulation of the T8 through T10 visceral afferent nerves, which results in periumbilical pain typically lasting 4-6 hours[23]; (3) intraluminal pressure exceeding local venous pressure in the appendiceal wall, producing vascular congestion and resultant tissue ischemia; (4) ischemia leading to inflammation and invasion of bacteria into the appendiceal wall; and (5) bacterial invasion and inflammation extending through the wall and into the surrounding tissue, leading to parietal peritoneal inflammation and focal pain, typically in the right lower quadrant (RLQ).[1,23,26-28] If this process is left unimpeded, eventually the diseased appendix will undergo necrosis and perforation. The time frame

Figure 1. Frequency Of Appendix Locations



for this process is highly variable. One study indicated that the period of abdominal pain averages 46 hours for gangrenous appendicitis and 71 hours in cases of perforation.[29] Other studies agree with this finding and have observed a perforation rate of over 80% when the diagnosis of appendicitis is delayed more than 48 hours from time of onset of pain.[30,31]

To be complete, in addition to acute and perforated appendicitis there is another entity described as "non-acute variant appendicitis." This term includes recurrent, subacute, and chronic appendicitis.[1,32] Of these 3 processes, recurrent appendicitis is described best in the literature, is most accepted by the surgical community, and has been estimated to occur in up to 9% of cases.[23,33] It is described as a patient with acute appendicitis who has had at least 1 episode of similar symptoms in the past.[34] The diagnoses of subacute and chronic appendicitis have been supported by case reports and a retrospective study of patients with abdominal pain for days to weeks that is relieved postappendectomy, often with evidence of appendiceal obstruction or inflammation.[32,35] Furthermore, 1% of patients with appendicitis report abdominal pain for 3 weeks prior to being diagnosed with appendicitis.[36] These limited data have reported that these cases have CT evidence of appendiceal inflammation. It is unknown why these patients do not experience perforation; however, these are variants to be aware of in the correct clinic circumstance. It is important to remember that history of prior abdominal pain has poor negative predictive value (NPV), and this should not dissuade the emergency clinician from pursuing the diagnosis if other factors in the history and examination are consistent with appendicitis.

The appendix is a vestigial organ whose function is not known. Traditionally, it has been premised to carry out an immunologic function due to the presence of a large amount of lymphoid tissue, but a more recent theory based on new findings postulates that the appendix is a potential reservoir for commensal bacteria. It is proposed that if the normal bacterial flora of the intestine are diminished, the appendix can offer "re-inoculation" of the colon.[37,38]

Differential Diagnosis

In all patients with suspected appendicitis, the differential diagnosis must include enteritis (in particular *Yersinia, Campylobacter,* and *Salmonella* which may or may not produce diarrhea), omental infarction, epiploic appendigitis, urinary tract infection (UTI), nephrolithiasis, hernia, bowel obstruction, cecal diverticulitis, cecal volvulus, and testicular torsion (in males).[39,40] Particularly in female patients of any age, the differential furthermore includes pelvic inflammatory disease (PID), ruptured ovarian follicle, tubo-ovarian abscess, ovarian torsion, and ectopic pregnancy.[5,6] In children, the differential diagnosis also includes necrotizing enterocolitis, intussusception, mesenteric adenitis, lower lobe pneumonia, and Meckel diverticulitis.[39] Ovarian and testicular torsion may occur in patients of any age, even infants and toddlers, so emergency clinicians must always be aware of the possibility of these high-risk diagnoses. For more information on pediatric testicular torsion, see the October 2011 issue of *Pediatric Emergency Medicine Practice,* "Evidence-Based Diagnosis And Treatment Of Torsion Of The Spermatic Cord In The Pediatric Patient." Of note, higher negative appendectomy rates are reported in females, owing to a larger number of possible alternative diagnoses.[41]

Because all elements should be considered to differentiate these diagnoses, the following elements should be considered. While diarrhea alone will not permit the exclusion of appendicitis, heme-positive diarrhea is more likely a sign of an entero-invasive organism. Determining if there are any other sick contacts or a travel history associated with diarrhea may also point toward the diagnosis of enteritis. Urinalysis findings of > 30 red blood cells (RBCs) per high-powered field or > 20 WBCs per high-powered field are more consistent with a UTI than ureteral inflammation due to an inflamed appendix.[5] Cervical motion tenderness is not specific for pelvic pathology and can be seen in peritoneal inflammation of any cause, but significant cervical discharge is more consistent with PID. Ovarian pathology and tubo-ovarian abscesses are easily discovered on pelvic ultrasound, which is a good first-choice study if there is a high suspicion for these diagnoses based on examination.

Prehospital Care

The prehospital care of the patient with presumed appendicitis is primarily supportive in nature. Patients should be kept nothing by mouth (NPO) and, if necessary, be provided with intravenous (IV) hydration or antiemetic medications for comfort. In the rare case of abdominal pain caused by a perforated appendicitis with septic shock or an alternative intra-abdominal/retroperitoneal disaster that leads to a hemodynamically unstable patient, aggressive fluid resuscitation and/or pressor therapy should be used as emergency medical service personnel deem appropriate.

Emergency Department Evaluation

Patients with appendicitis will vary widely in the severity of their presentation. Abdominal pain of any severity must be taken seriously by triage staff and an initial assessment performed as quickly as possible. Disrobe all patients and place females in a

room with privacy and the capacity for performing a full gynecological examination.

The clinical presentation of acute appendicitis is more often atypical than typical. The traditional teaching is that a typical case of appendicitis occurs in a teenager or young adult who presents with abdominal pain initially in the midepigastric area, migrating to the right lower quadrant (RLQ) and progressively worsening over 12 to 24 hours.[1] A case containing all of these "typical" components constitutes only a small minority of all appendicitis cases (as low as 6% in one study).[1,41] Therefore, a high clinical suspicion for appendicitis must always be present in patients of all ages with abdominal pain.

No single history or physical examination finding can either reliably diagnose or rule out appendicitis; however, some symptoms and signs have been found to be more commonly associated with appendicitis. A common mistake is to rely on a single symptom or sign to either include or exclude appendicitis from the differential; research has demonstrated that physicians do this at their peril. Rather, studies have indicated that one should take multiple elements from the patient's history, physical examination, and basic laboratory data in order to risk stratify them. The emergency clinician should then utilize this data to determine the need for imaging and the best treatment plan and disposition for the patient.[5,41-44]

The history and physical examination focus on eliciting features that best discriminate appendicitis from other causes of abdominal pain. This is best done by determining positive and negative likelihood ratios (LRs). By combining individual symptoms, signs, and laboratory values, a diagnostic profile of the patient is created that maximizes diagnostic accuracy.[41-43] This is the concept behind scoring systems for appendicitis (eg, Alvarado Score), which will be discussed in following sections. Therefore, it is vital that the clinician: (1) keep a high clinical suspicion for appendicitis, (2) fabricate a solid pretest probability for each patient by utilizing those symptoms, signs, and laboratory markers that best differentiate appendicitis, and (3) use the assessment to determine the appropriate diagnostic plan and disposition for each individual patient. **See Table 2** for a summary of the most recent applicable data on history, physical examination, and laboratory findings in appendicitis.

History

Symptoms elicited on history that are most predictive of appendicitis are: (1) migration of pain from the periumbilical or midepigastric area to the RLQ,[10,11,41-44,46] (2) presence of RLQ pain,[10,11,44] and (3) presence of pain prior to vomiting.[11,44] Components of a patient's history that are only mildly useful in helping to diagnose appendicitis are vomiting and male gender.[41,43] Symptoms that have a high negative predictive value (ie, if the patient has these symptoms, then it implies that the patient may not have appendicitis) include absence of RLQ pain and the presence of similar pain in the past (although recurrent appendicitis is still a possible emergent diagnosis in these patients).[11,44] Furthermore, symptoms that have been commonly ascribed to appendicitis that have been found to not have any positive or negative effect in helping to make the diagnosis include anorexia, nausea, and aggravation by cough or movement.[10,11,41-44]

In a meta-analysis by Wagner et al of over 4000 patients in 10 studies, it was determined that the 3 most valuable aspects of a patient's history are RLQ pain (+LR = 8), migration of pain from the periumbilical region to the RLQ (+LR = 3.1), and the presence of pain prior to vomiting (+LR = 2.76). The most valuable symptoms that assisted in excluding appendicitis were absence of RLQ pain or presence of similar pain in the past (-LR = 0.2 and 0.3, respectively). Symptoms that did not improve accuracy include nausea and anorexia (ie, hamburger sign). Although other literature has reported that more than 90% of patients with appendicitis complain of anorexia[1] and this study demonstrated anorexia to be moderately sensitive at 68%, anorexia had a low enough specificity (36%) in this meta-analysis to imply that it is not very useful in appendicitis (+LR = 1.27 [95% confidence interval (CI), 1.16-1.38] and -LR = 0.64 [95% CI, 0.54-0.75]).[11,44]

Andersson et al prospectively studied the diagnostic value of 21 elements of history, physical examination findings, and laboratory data in 496 patients over the age of 10 with suspected appendicitis. This study found that the aspects of history that best contributed to a diagnosis of appendicitis were male gender (+LR = 1.67 [95% CI, 1.4-2.0]), vomiting (+LR = 1.83 [95% CI, 1.4-2.4]), migration of pain (+LR = 1.47 [95% CI, 1.2-1.8]), duration of symptoms of 7 to 12 hours (+LR = 1.66 [95% CI, 1.1-2.6]), a patient rating his or her pain as "high intensity" (+LR = 1.52 [95% CI, 1.2-1.9]), and age > 40 years (+LR = 2.25 [95% CI, 1.3-4]). In addition, this study found there to be no diagnostic value in elements such as family history of appendicitis, anorexia, nausea, and diarrhea.[43]

Andersson et al performed a meta-analysis of 28 variables in 24 studies (23 of which were prospective trials) involving 5833 patients where the study subjects were all admitted to a hospital for possible appendicitis (ie, observation vs surgery). This meta-analysis found that of all elements of the patient's history, no single element had significant utility and only migration of pain and vomiting were minor discriminators of appendicitis (+LR = 2.06 [95% CI, 1.6-2.6] and 1.63 [95% CI, 1.45-1.84], respectively).[42]

Laméris et al performed a prospective study involving a consecutive series of 1101 patients aged 19 years and older who presented to an ED with

atraumatic abdominal pain. Although this study did not show any aspects of clinical history to be very effective in distinguishing appendicitis, it did demonstrate the most significant aspects of history were male gender (+LR = 2), migration of pain (+LR = 1.7), and vomiting (+LR = 2).[41]

Lastly, according to the 2010 ACEP Clinical Policy on patients with suspected appendicitis, the most useful aspects on a patient's history to assist in diagnosing appendicitis include RLQ pain, pain migration, and pain progression.[10]

Physical Examination

Similar to a patient's history, no single individual sign on physical examination can diagnose or exclude appendicitis; however, several studies have implied that certain elements of the examination have varying degrees of accuracy in helping to diagnose appendicitis. Signs on physical examination that are most predictive of appendicitis are RLQ tenderness and rigidity.[11,41,43,44] Signs that demonstrated a small effect to discriminate appendicitis were other peritoneal signs (rebound tenderness, guarding, percussion tenderness), temperature above 38.3°C (101°F), and the presence of a psoas sign.[11,44,45] Signs that do not help in diagnosing appendicitis include tenderness on rectal examination, increased local skin temperature of RLQ, and Rovsing sign (ie, pain in the RLQ upon palpation of the LLQ).[5,47,48]

Although most studies have shown nondifferentiated RLQ tenderness to be a decent discriminator in appendicitis, it has been demonstrated that tenderness at McBurney's point is particularly specific in appendicitis.[41,43] McBurney's point lies one-third of the distance from the anterior superior iliac spine (ASIS) on a line that runs from the ASIS to the umbilicus on the right side of the abdomen.[49]

Despite the presence of the iliopsoas sign having a specificity of 79% to 95% in cases of appendicitis, its sensitivity is low (13%-42%) and one study showed that only 5 out of 113 physicians (4%) correctly performed the iliopsoas test.[11,50,51] The appropriate manner in which to perform the iliopsoas test for appendicitis is to have the patient lie on his left side and passively extend his right leg at the hip while both knees are extended. A positive psoas sign is elicited when the patient has abdominal pain with this maneuver.[11,52]

There is only one published study on the obturator sign in appendicitis. In this study, Berry et al found the sensitivity of this sign to be only 8%, with a 94% specificity.[53] The obturator sign is elicited in the supine patient as the examiner internally and externally rotates the patient's right leg as it is flexed at the hip.[52,53]

In addition to a thorough abdominal examination that includes palpation to elicit peritoneal signs and possibly iliopsoas or obturator testing, the examining physician must always perform a thorough genitourinary (GU) examination as well. In males, a GU examination must look for hernias or testicular pathology, while in females, a complete pelvic examination must be performed to assess for elements of gynecologic pathology. Of note, cervical motion tenderness is neither sensitive nor specific for gynecologic pathology, is a sign of nonspecific peritoneal inflammation, and has been found to occur in up to 28% of female patients with appendicitis.[54]

A meta-analysis by Wagner et al found the signs most likely to be associated with appendicitis to be: rigidity (+LR = 4), positive psoas sign (+LR = 2.38), and fever (+LR = 1.94). The positive LR of rebound tenderness varied too much to make definitive recommendations (+LR = 1.1-6.3). Guarding and rectal tenderness were not found to be significant signs.[11]

In 1999, Andersson et al prospectively studied the diagnostic value of 21 elements of history, physical examination findings, and laboratory data in 496 consecutive patients over the age of 10 with suspected appendicitis and found that, overall, physical examination findings had better discriminatory effect than the patient's history. Rebound tenderness (+LR

Table 2. Elements Of History, Physical Examination, And Laboratory Values And Their Utility In Diagnosing Appendicitis

	Moderately Useful	Slightly Useful	Not Useful
History	• Migration of pain • RLQ pain • Pain prior to vomiting	• Vomiting • Male gender	• Anorexia • Nausea • Pain worse with cough/movement
Physical examination	• RLQ tenderness • Abdominal wall rigidity	• Rebound tenderness • Guarding • Percussion tenderness • Temperature > 38.3°C (101°F) • Psoas sign	• Rectal examination • Rovsing sign • Increased RLQ skin temperature
Laboratory values	WBC ≥ 10 **AND** CRP ≥ 8	• WBC >15 • PMN > 85%	WBC >10

Abbreviations: CRP, C-reactive protein; PMN, polymorphonuclear leukocyte; RLQ, right lower quadrant; WBC, white blood cell count.

= 7.87-1.46), guarding (+LR = 7.45-1.91), temperature above 38.5°C (101.3°F) (+LR = 3.01), and localized tenderness over McBurney's point (+LR = 2.01) were moderate predictors of appendicitis. The ranges of likelihood ratios in this study were due to the fact that the authors delineated the presence of each sign into *none*, *slight*, *moderate*, or *strong* and gave each value an individual LR. This study furthermore found that rectal tenderness had no diagnostic value and appendicitis was less likely if abdominal tenderness was absent (-LR = 0.1) or guarding or rebound tenderness were absent (-LR = 0.3 and 0.24, respectively).[43]

Andersson's 2004 meta-analysis of 28 variables in 24 studies where subjects were admitted to a hospital for possible appendicitis found that the best signs of appendicitis were those involving peritoneal irritation: rebound tenderness (+LR = 1.99 [95% CI, 1.6-2.5]), percussion tenderness (+LR = 2.86 [95% CI, 2.0-4.2]), guarding (+LR = 2.48 [95% CI, 1.6-3.8]), and rigidity (+LR = 2.96 [95% CI, 2.4-3.6]). Fever was found to only have mild effect in helping to diagnose appendicitis, with temperatures above 38.5°C (101.3°F) having a +LR = 1.64 (95% CI, 0.7-5.3).[42]

Laméris et al performed a prospective study involving a consecutive series of 1101 patients aged 19 years and above who presented to an ED with atraumatic abdominal pain. This study showed the strongest physical examination findings in appendicitis were RLQ tenderness (+LR = 1.1) and rigidity (+LR = 1.9).[41]

Cardall et al performed a prospective consecutive case series of all patients presenting to the ED with possible appendicitis and measured their temperature and WBC count. This study demonstrated that although temperatures lower than 38.27°C (100.9°F) were very poor discriminators, temperatures from 38.3°C to 38.8°C (101°F-102°F) were moderately helpful (+LR = 2.38) and temperatures above 38.8°C (102°F) were even more discriminatory in appendicitis (LR = 3.18).[45]

In addition to a complete abdominal examination, the emergency clinician must examine related systems to elucidate alternative diagnoses. These include auscultating the lungs for lower lung field findings of pneumonia, examining the testicles for signs of torsion or epididymitis, and performing a complete pelvic examination on females for signs of PID or ovarian/tubular pathology. Particularly in children, the emergency clinician should assess for signs of compensated shock such as tachycardia, cool or clammy skin, altered mental status, or prolonged capillary refill.

Diagnostic Studies

Laboratory Tests

Laboratory tests that are ordered as part of the evaluation of appendicitis are similar to those needed in any patient with abdominal pain and should include a complete blood count (CBC), basic metabolic panel, liver function tests, lipase, urinalysis, and human chorionic gonadotropin (hCG) (in females). Contrary to common teaching in emergency medicine, there is evidence to support the use of laboratory data to assist in the diagnosis of appendicitis. This evidence derives from both prospective trials and meta-analyses and is promoted in the ACEP 2010 Clinical Policy regarding evaluation of ED patients with suspected appendicitis.[10,41-43] The laboratory tests that have demonstrated the greatest value in discriminating appendicitis are the WBC count (noted here as a single integer that represents n = x 10^9 cells/L), polymorphonuclear leukocyte (PMN) count (noted as a percentage), and the CRP level (noted as mg/L). Numerous studies have supported that leukocytosis alone, as a marker of inflammation, is not a reliable independent predictor of appendicitis, and its absence alone cannot effectively rule out appendicitis.[45,55,56] The greatest value is realized when the findings of these different tests are combined.[10,41-43,45] Laboratory analysis should not be regarded as definitively diagnostic in acute appendicitis. Rather, laboratory testing has an important role in offering contributing information that must be integrated into the patient's history and physical examination to create the most accurate assessment possible in potential appendicitis cases.[10,42,43] Based only on history and physical examination, men are correctly diagnosed with appendicitis 78% to 92% of the time and women only 58% to 92% of the time, which makes supplementary testing an important aid in diagnosing appendicitis.[55]

Andersson et al prospectively studied the diagnostic value of 21 elements of history, physical examination findings, and laboratory data in 496 patients over the age of 10 years with suspected appendicitis and found that the independent WBC count, PMN count, or CRP level had similar accuracies in predicating appendicitis as clinical findings such as rebound tenderness and guarding. While the likelihood of appendicitis was only mildly increased with WBC counts of 12 to 15 (+LR = 2.44 [95% CI, 1.63-3.65]), the discriminatory value of inflammatory markers significantly increased at WBC counts > 15 (+LR = 7.03 [95% CI, 4.11-12.15]) and PMN > 85% (+LR = 4.46 [95% CI, 3.13-6.42]). Furthermore, patients in this study with WBC < 8 or PMN < 70% (+LR = 0.16 [95% CI, 0.10-0.26] and +LR = 0.15 [95% CI, 0.08-0.25], respectively) were moderately less likely to have appendicitis. Interestingly, this study also found that CRP level alone did not have significant power in finding appendicitis (+LR = 1.74-2.20 [95% CI, 0.25-3.20]). This study demonstrates that contrary to popular belief, the WBC count and PMN count had similar discriminatory capacity in appendicitis as RLQ tenderness or rigidity and were better than historical elements such as pain migration or

the presence of pain prior to vomiting. This study furthermore found that for advanced appendicitis (defined as either histologic gangrene of the appendix, perforation, or localized abscess formation), the WBC count and PMN count had even higher rates of prediction for appendicitis. However, this study has a major limitation when considering its ability to generalize results to the emergency patient population. The study included patients who were admitted to the hospital for suspected appendicitis and the authors note that in 420 patients, a repeat laboratory examination was performed after a median of 6 hours of observation. In this group of patients, the result of the last examination was used in the analysis. Therefore, much of the data that were provided do not represent an initial laboratory result measure as would occur in the ED, but rather a delayed measure.[43]

In a study by Cardall et al, the authors prospectively studied 293 consecutive ED patients aged 7 to 75 years who had suspected appendicitis. Admitted patients were followed for surgical or clinical outcome while discharged patients were followed via a telephone interview 2 weeks after the initial ED visit. The authors concluded that an abnormal WBC count (defined as WBC > 10) had a +LR = 1.59 [95% CI, 1.31-1.93] and a -LR = 0.46 [95% CI, 0.31-0.67], thereby making the WBC count a poor discriminator in appendicitis.[45]

Laméris et al performed a prospective study involving a consecutive series of 1101 patients aged 19 years and above who presented to an ED with atraumatic abdominal pain. This study demonstrated that a WBC > 15 was a weak predictor of appendicitis (+LR = 2.1 [95% CI, not reported]). Although CRP levels alone did not correlate well in either a positive or negative manner, the combination of CRP < 12 and WBC < 10 had a -LR = 0.09 (95% CI, 0.03-0.3) and a +LR = 1.4 (95% CI, 1.2-1.7). This implies that in all patients except those with a very high pretest probability, if the CRP level and WBC counts are below these values, there is a strong likelihood against appendicitis.[41]

As previously stated, combining laboratory markers of inflammation allows one to increase accuracy in diagnosing appendicitis. In a meta-analysis by Andersson et al that included 24 studies and 5833 patients, the authors reported that combining WBC > 10 and CRP > 8 offers a +LR = 23.32 (95% CI, 6.87-84.79) and a -LR = 0.03 (95% CI, 0.0-0.14). According to this analysis, these 2 laboratory values combined can have a very strong effect helping to include (if both are positive) or exclude (if both are negative) the diagnosis of appendicitis. Additionally, this study found that the combination of guarding or rebound on examination and WBC > 10 was also a solid discriminator of appendicitis (+LR = 11.34 [95% CI, 6.65-19.56]). Other findings in this study include: (1) WBC > 10 with +LR = 2.47 (95% CI, 2.06-2.95); (2) WBC > 15 with +LR = 3.47 (95% CI, 1.55-7.77); (3) PMN > 75% with +LR = 2.44 (95% CI, 1.6-3.75); and (4) PMN > 85% +LR = 3.82 (95% CI, 2.86-5.08).[42]

Urinalysis may be abnormal in appendicitis in up to 48% of cases. Findings of pyuria, hematuria, and bacturia may be present, and care must be taken to not be misled by an abnormal urine examination. These abnormal results are thought to be the result of an inflamed appendix abutting the ureter, resulting in ureteral inflammation.[5,58] Of note, urinalysis findings of > 30 RBCs per high-powered field or > 20 WBCs per high-powered field are more consistent with a UTI.[5]

In summary, there is poor diagnostic utility for the use of abnormal WBC count (> 10) alone in the diagnosis of acute appendicitis, with sensitivity 76% to 77%, specificity 52% to 63%, positive predictive value (PPV) 42% to 64%, and NPV 77% to 82%. An abnormal WBC > 10 also appears to have low discriminatory power with +LR = 1.59-2.47 and -LR = 0.25-0.46.[41-43,45] Using interval LRs at different WBC count ranges can improve the predictive power for diagnosing acute appendicitis, particularly if a patient's WBC count is > 15, and higher WBC count values also appear to be predictive for more advanced appendicitis (gangrenous or perforated appendicitis).[42,43] The PMN count and CRP levels, by themselves, appear to have only moderate predictive power as well, with +LR = 3.82-4.46 for PMN > 85% and +LR = 1.1-4.24 for CRP > 10.[41,42] By combining WBC > 10 and CRP > 8 or guarding/rebound and WBC > 10, the emergency clinician can achieve levels of predictive power that are of great value in the assessment of appendicitis.[42] Of note, evidence of inflammation on a patient's urinalysis may mislead the clinician and should not be relied on to exclude appendicitis.

Plain Radiographs

Findings on either plain radiographs or barium enema studies in patients with appendicitis are nonspecific, very insensitive, and of little clinical value in making the diagnosis.[1,5,11,59] The greatest value of plain radiographs is to quickly rule out other potential causes of abdominal pain such as obstruction or perforation.[60] Although CT is more sensitive for detecting bowel obstruction and small amounts of free air, plain radiographs can most often be performed in a much more efficient fashion in most EDs and are accurate enough in these conditions to warrant their use if the clinician has a high degree of suspicion for these disease entities.[61-65] An important concept to consider is that findings of bowel obstruction on plain radiographs may be the result of a perforated appendix.[64] It has been well documented that peritoneal inflammation from a perforated appendix may result in an ileus with resultant bowel obstruction pattern found on

imaging. Therefore, if the history and examination are leaning towards appendicitis and radiographs demonstrate obstruction, consider proceeding to a CT. This is especially relevant in patients with peritoneal signs or fever and in those with no prior history of abdominal surgeries that would normally predispose one to bowel obstruction.[64]

Computed Tomography

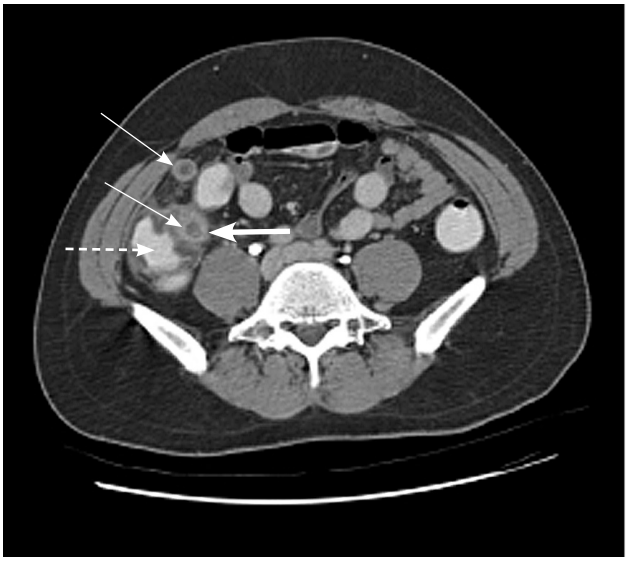
Computed tomography is a very effective means for diagnosing all stages of appendicitis.[23,63] It is commonly available in most EDs, is not operator-dependent, can be interpreted by most radiologists and surgeons, and is not limited by body habitus (as compared with ultrasound).[23] The value of CT in diagnosing appendicitis has been reported as follows: (1) sensitivities of 90% to 100%, (2) specificities of 91% to 99%, (3) PPVs of 92% to 98%, and (4) NPVs of 95% to 100%.[5,23,65,66] A meta-analysis by Terasawa et al of 12 prospective studies involving 1172 patients demonstrated that CT had a sensitivity of 94% and specificity of 95% and a +LR = 12.3 (95% CI, 9.9-17.9) and a -LR = 0.09 (95% CI, 0.07-0.12) for diagnosing appendicitis.[67]

On CT, the normal appendix has the appearance of a tubular, pericecal structure that is either totally collapsed or partially filled with fluid, air, or contrast, with homogenous-appearing periappendiceal fat.[23] In acute appendicitis, diagnostic findings on CT scan include: (1) enlarged appendiceal diameter (> 6 mm with surrounding inflammation or > 8 mm without such changes),[68] (2) appendiceal circumferential wall thickening > 2 mm with mural enhancement (this may create a "target sign"),[23] (3) calcified appendicolith (may be seen in up to 30% of cases), and (4) signs of periappendiceal inflammation (eg, fat stranding, clouding of the adjacent mesentery, and periappendiceal fluid).[21,23,69] **(See Figures 2 and 3.)** "Tip appendicitis" pertains to obstruction and inflammation limited to the distal tip of the appendix and is a subtle finding on CT that may lead to a false-negative interpretation. Ideally, the appendix should be followed from its cecal base to its most distal portion in order to identify any areas of inflammation and avoid missing the diagnosis.[25]

In general, if the appendix is not visualized and there are no findings of inflammation in the RLQ, then the diagnosis of appendicitis can be excluded.[68,70] The one caveat to this statement is that it does not apply to patients who have low amounts of intra-abdominal body fat. Often, inflammation of intra-abdominal fat provides an important marker that is absent in lean patients.[70,71] The diameter of the normal, nondiseased appendix varies from 5 to 11 mm, so the other signs of appendicitis listed previously must be factored in when making the diagnosis of appendicitis on CT.[21,23]

Multiple good-quality studies have demonstrated the value of CT in diagnosing appendicitis; however, questions often arise regarding its effect on decreasing negative appendectomy rates, the effect of ionizing radiation for future risk of malignancy, and the optimal technique for detecting appendicitis.

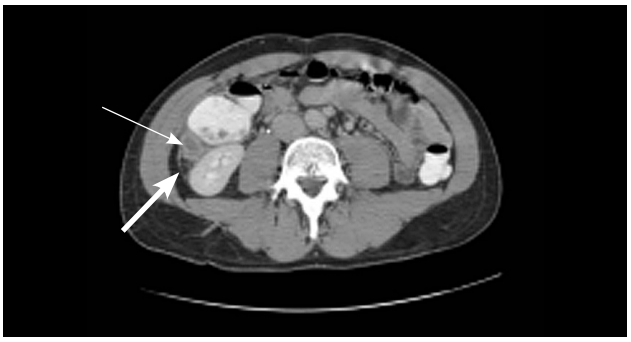
Figure 2. Computed Tomography Of Appendicitis With Oral And Intravenous Contrast



Computed tomography of appendicitis in a 44-year-old male, performed with oral and intravenous contrast. Note the appendix unfilled with enteric contrast (thin arrows), the thickened appendiceal wall (thick arrow), and the arrowhead sign (dashed arrow). The arrowhead sign is representative of cecal wall thickening due to extension of appendiceal inflammation into the cecum.

Used with permission of Michael Cole, MD.

Figure 3. Computed Tomography Of Appendicitis With Oral Contrast



Oral-contrast-enhanced computed tomography of appendicitis in a 22-year-old male. Note the appendix is not filled with enteric contrast (thin arrow) and is surrounded by the contrast-filled cecum. Periappendiceal stranding is denoted by thick arrow.

Used with permission of Michael Cole, MD.

Although some retrospective studies have implied that CT does not change the rate of negative appendectomies,[46,66] there have been a number of solid studies and meta-analyses that have demonstrated the effectiveness of CT in reducing the number of unnecessary procedures.[72-76]

Rao et al performed a prospective study on a consecutive series of 100 patients in the ED who had suspected appendicitis based on history, physical examination, and laboratory data. Treatment plans made prior to CT were compared to those after CT, and the patients were followed based on histologic findings of appendicitis postoperatively or at 2-month clinic follow-up in those with no operative intervention. The CT findings resulted in changes in the treatment of 59 patients, including avoiding unnecessary surgery in 13 patients. Furthermore, this study found the accuracy of CT in diagnosing appendicitis to be 98% and average cost savings by using CT to be $447 per patient due to avoiding nonessential admissions for observation and unnecessary surgical intervention.[72]

Another prospective study by Wilson et al followed 99 patients presenting to the ED with suspected appendicitis. An initial clinical impression was obtained by a surgical consultation, and then patients underwent RLQ ultrasound, RLQ/pelvic focused CT with rectal contrast, and a second serial abdominal examination. Although the ultrasound did not affect any initial treatment plans, CT results and repeat examination reduced the potential negative appendectomy rate from 50% to 17%, spared 6 female patients from a negative appendectomy, prevented 13 patients from being admitted unnecessarily, and expedited surgery for 10 patients who were going to be admitted for observation but had findings of appendicitis on CT. Interestingly, CT failed to detect a normal appendix in 2 males who underwent a negative appendectomy despite imaging. Overall, CT was useful in changing disposition on a significant number of patients and resulted in a cost savings of $206 per patient.[73]

A recent study that analyzed 3540 patients from a database in the Washington State Surgical Care and Outcome Assessment Program found that hospitals that utilized ultrasound or CT in assessment of patients with potential appendicitis had lower rates of negative appendectomies. Overall, the rate of negative appendectomy was determined to be 4.5% in patients that had ultrasound or CT versus 9.8% in those who did not undergo imaging, thereby implying the value of imaging in possible appendicitis.[77]

Although CT does decrease the negative appendectomy rate, the next question is: If the patient has an unequivocal history and physical examination (especially in male patients), should he be taken directly to surgery without advanced imaging? Ultimately, this is the surgeon's decision and underscores the point that surgical consultation early in the ED course is beneficial to the patient's overall care. Research does offer some guidance in the form of clinical scoring systems for appendicitis (discussed on page 16); however, there is currently no universally agreed-upon constellation of signs and symptoms that clearly distinguishes which patients should undergo imaging prior to operative intervention.

A critical concern for the use of CT in appendicitis is the dose of ionizing radiation affecting the patient. A CT scan of the abdomen typically doses the patient being examined with 10 mSv, which is approximately the same radiation dose as 500 chest radiographs or approximately 4.5 years of natural background radiation.[78,79] At this dose of ionizing radiation, there is an excess risk of radiation-induced cancer of 1 in 2000 patients undergoing the study.[80,81]

In children, the risk is even greater. As a result of their altered body habitus and increased "incubation time" to develop cancer, one study using mathematical modeling estimated the lifetime risk of malignancy in a 1-year old child from a single abdominal CT to be 1 in 550.[82] Radiation exposure from CT is a definite concern and one that the astute clinician should keep in mind. Often, the physician's concern for the short-term risk of malpractice supersedes the regard for long-term risk of radiation to the patient. A discussion of risks, benefits, and alternatives should occur between the patient and provider in all but the most unequivocal cases, particularly in younger patients.

One method of reducing radiation exposure during CT for appendicitis is to perform a focused RLQ CT. In a prospective trial of 100 consecutive patients older than 6 years of age with clinical suspicion of appendicitis, Rao et al examined the effectiveness of a protocol in which a focused/limited CT scan of the RLQ and pelvis was performed after only rectal contrast was administered (ie, no IV or PO contrast). In patients requiring operative intervention, CT scan results were confirmed by surgical or pathologic findings and all other patients were followed via phone calls at 1 week and 2 months. This study demonstrated a sensitivity, specificity, PPV, and NPV of 98% and accuracy equal to that of full abdominopelvic CT scans with PO and IV contrast in detecting or excluding appendicitis. Furthermore, using this protocol, each study was completed in 15 minutes, did not expose the patient to iodinated IV contrast, was associated with one-third less radiation exposure, and was one-half the cost of a full abdominopelvic CT. In addition, this limited technique did not miss any significant pathology outside of the RLQ and found alternative diagnoses in 62% of patients that were not found to have appendicitis on CT. These alternative diagnoses included mesenteric adenitis, ovarian cyst, colitis, sigmoid diverticulitis, and tubo-ovarian abscess.[83]

Other studies have also shown utility of focused

RLQ/pelvis CT: (1) in adults using PO or rectal contrast,[84] (2) in children using rectal contrast,[85,86] and (3) in children using PO and IV contrast.[87] Of note, in these studies, there were a very limited number of serious alternative diagnoses that were missed by using this focused examination method. In summary, focused RLQ/pelvic CT is best used in patients with a high likelihood of appendicitis, in patients with a low likelihood of other alternative diagnoses, and in populations for whom the risk of radiation is the greatest (ie, young patients, pregnant patients, premenopausal females).[88]

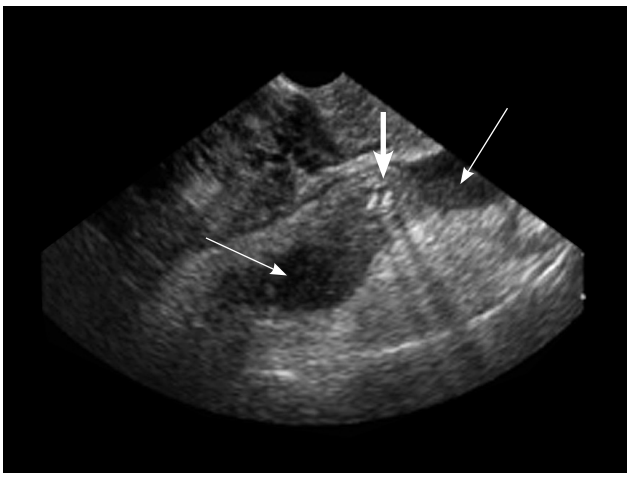
There are 2 major components of CT protocol that should be addressed. The first is considering a limited RLQ/pelvic CT rather than a complete abdominal study, which was discussed earlier. The second is whether or not to administer contrast (PO, PR, or IV) in suspected appendicitis cases. A recent ACEP policy statement on this issue states that IV and oral contrast may increase the sensitivity of CT for the diagnosis of appendicitis, but it is acceptable to perform CT scans for appendicitis with or without PO, PR, or IV contrast.[10] Enteric contrast assists in demarcating the appendix from surrounding structures, while IV contrast aids in accentuating periappendiceal and luminal inflammation.[89,90] Oral contrast should opacify the ileocecal portion of the intestine within 45 to 60 minutes.[23] Rectal contrast is a viable alternative and can be administered just prior to the CT examination, thereby limiting the time necessary to perform the examination. A recent study by Berg et al demonstrated that the use of rectal contrast can decrease ED length of stay by 1 hour without significant patient discomfort or decreased patient satisfaction.[91] According to ACR Appropriateness Criteria® for RLQ pain in suspected appendicitis (2010), both enteric (either PO or rectal) and IV contrast are recommended in adults, children, and pregnant women (if CT is necessary in the gravid patient) provided there are no contraindications to IV contrast (ie, allergy or renal insufficiency). However, this ACR guideline states that in the specific scenario of a "typical" case of appendicitis (ie, fever, RLQ pain, leukocytosis), IV contrast may be omitted.[88] This guideline explains why most of our radiology colleagues are hesitant to perform noncontrast studies.

Ultrasound

Advances in ultrasound quality and a novel technique called *graded compression* have improved the sensitivity of ultrasound for identifying appendicitis.[1] Graded compression is a technique whereby steady pressure is applied to the RLQ in order to reduce bowel gas and collapse the normal bowel to assist in visualizing the appendix. Appendicitis is diagnosed on ultrasound when a noncompressible appendix with a diameter > 7 mm is visualized.[1,71] **(See Figure 4.)** Other findings to aid in the diagnosis include echogenic shadowing as a result of an appendicolith, periappendiceal echogenic fat (as a sign of inflammation), or periappendiceal abscess.[71] Although certain specialized centers may regard nonvisualization of the appendix as having a high NPV in ruling out appendicitis, most radiologists would consider a nonvisualized appendix as a nondiagnostic study, thereby requiring a secondary study such as CT or magnetic resonance imaging (MRI) in order to definitively exclude the diagnosis.[71] A major disadvantage of ultrasound is that it is operator-dependent. Body habitus, increased intestinal gas, and the retrocecal location of the appendix have been noted to result in nondiagnostic images.[92,93]

Two recent meta-analyses demonstrated higher sensitivity and specificity for CT than ultrasound.[94,95] Although a prospective trial by Keyzer et al suggested that the accuracy of ultrasound and CT were similar, this trial was affected by a small sample size, and the frequency of inconclusive examinations was greater with ultrasound.[96] Overall, meta-analyses involving ultrasound in appendicitis have demonstrated a sensitivity of 78% to 94% and a specificity of 81% to 94%. A meta-analysis by Terasawa et al of 14 prospective studies involving 1516 patients demonstrated that ultrasound has a +LR = 5.8 (95% CI, 3.5-9.5) and a -LR = 0.19 (95% CI, 0.13-0.27) for the diagnosis of appendicitis and found that ultrasound was not as accurate at predicting appendicitis when compared with CT.[67] Garcia Peña et al published a prospective cohort study of 139 patients aged 3 to 21 years with equivocal findings

Figure 4. Ultrasound Image Of Dilated Appendix



Ultrasound image of appendicitis in an 8-year-old female. Note the dilated noncompressible appendix (thin arrows) and the presence of a fecalith with posterior acoustic shadowing (thick arrow).

Used with permission of Michael Cole, MD.

for appendicitis and found that ultrasound resulted in a significant change in management in 18.7% of children, while limited RLQ CT scan changed management in 73.1% of patients.[85] In this study, a negative ultrasound result (ie, the appendix was not visualized) did not have any effect on the surgeon's confidence in excluding appendicitis. This underlies the major weakness with ultrasound: if the imaging does not visualize appendicitis, then it is considered a nondiagnostic study with poor predictive value.

The ACR Appropriateness Criteria® (2010) and ACEP Clinical Policy (2010) on suspected appendicitis both support an algorithm where ultrasound can be used as the diagnostic study of first choice in children and pregnant patients after complete history, physical examination, and laboratory data determine that appendicitis is the most likely diagnosis and other alternative diagnoses are less likely.[10,88] Ultrasound has been demonstrated to be of greater clinical utility in children, where the risk of ionizing radiation is of more concern and increased body habitus is less common. A retrospective study of pediatric patients by Hernandez et al demonstrated that ultrasound reduced the negative appendectomy rate from 20% to 3% versus clinical examination alone and was 100% sensitive for appendicitis in the 389 patients studied.[97]

Ultrasound is safe during all trimesters of pregnancy and should be the primary initial imaging study of choice in pregnant women with suspected appendicitis. The sensitivity of ultrasound in pregnancy varies from 66% to 100%, with a specificity of 95% to 96%.[98]

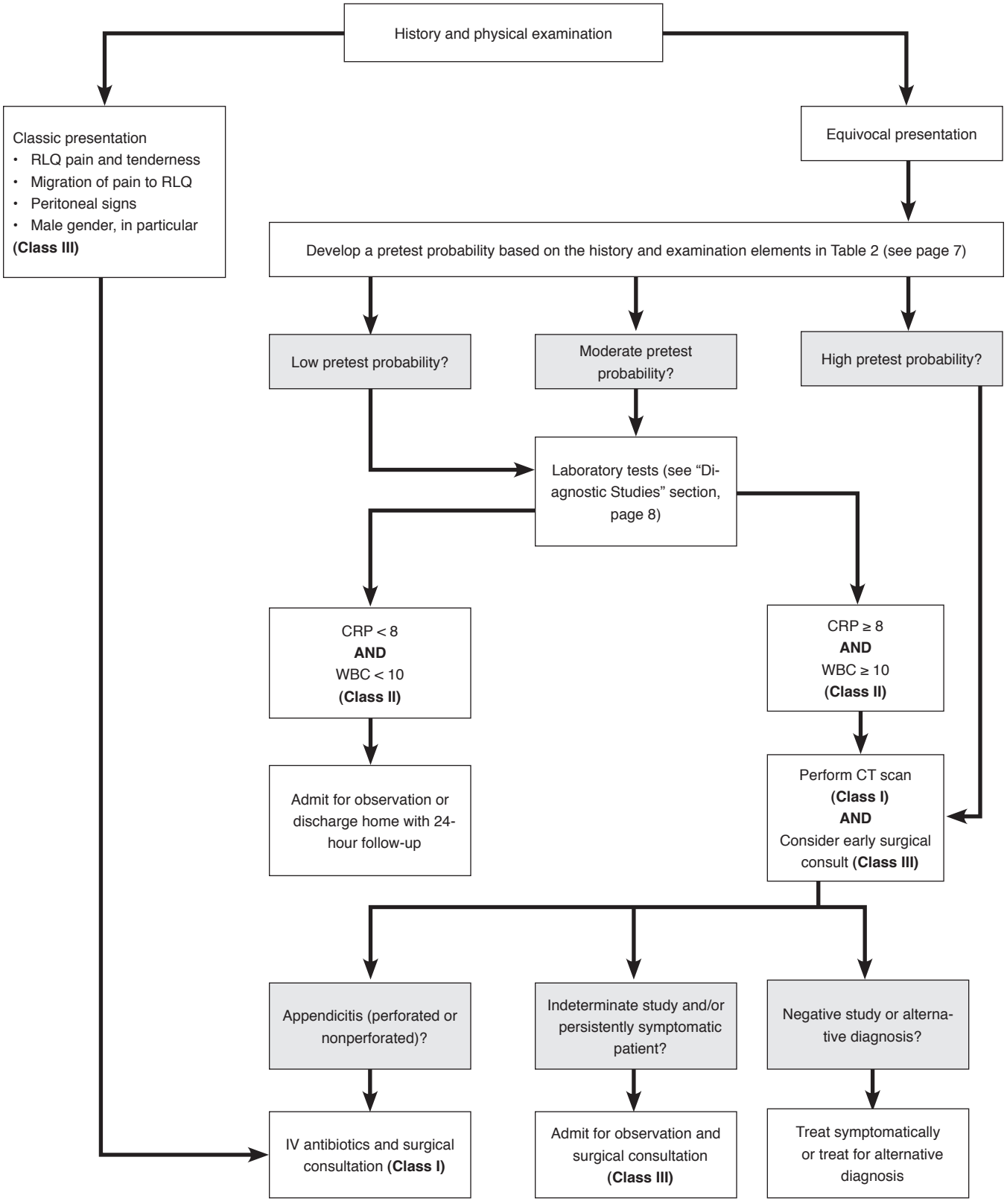
Although there is no consensus for utilizing ultrasound as the primary diagnostic choice for imaging appendicitis in nonpregnant adult patients, Laméris et al performed a prospective study of 1021 patients that demonstrated the value of choosing ultrasound as the initial test in all adult patients with abdominal pain requiring imaging.[99] The inclusion criteria in this study were all nonpregnant patients over 17 years of age with nontraumatic abdominal pain for more than 2 hours and less than 5 days who were found to have a history and physical examination that required further imaging. Patients with "benign" presentations and those with gastrointestinal bleeding or hemodynamic instability were excluded. Qualifying patients underwent abdominal radiograph, ultrasound, and CT, and patient outcomes were assessed at 6 months. When the data were examined to determine which imaging test or combination of tests resulted in optimal outcomes, it was found that the imaging strategy that resulted in the greatest sensitivity and the least number of missed urgent diagnoses was a "conditional CT strategy," whereby ultrasound was initially performed on all patients, followed by CT in the patients who were not found to have definitive evidence of appendicitis. This protocol resulted in a sensitivity of 94%, had the lowest missed-diagnosis rate (ie, false-negative rate) of any other single or multitest strategy, and would potentially reduce the use of CT by 50%. However, this conditional strategy had a false-positive rate of 16% (vs 12% when ultrasound was avoided and every patient received only CT). Other studies have also promoted this conditional CT strategy with good results, although these studies have all taken place in academic institutions with radiologists who are skilled in graded compression ultrasound—a benefit that most clinicians do not have.[100,101] Nevertheless, ultrasound may be considered as an initial study of choice in young adult patients (particularly females) where radiation is more of a concern; however, there is not definitive evidence to support this concept as standard practice in most institutions.

In summary, ultrasound is a powerful tool in aiding in the diagnosis of appendicitis due to its accuracy and lack of ionizing radiation. This is of particular importance in children and gravid patients. However, ultrasound is operator-dependent and is most reliable in centers that perform high volumes of studies. If the ultrasound does not visualize evidence of appendicitis, then it is considered nondiagnostic, and a more definitive examination (such as CT or MRI) must be used. Rarely, ultrasound will demonstrate a noninflamed appendix and the examination will be interpreted as negative; however, in persistently symptomatic patients, the accuracy of a negative ultrasound must be questioned, and either admission, CT, or MRI must be strongly considered.

Magnetic Resonance Imaging

Magnetic resonance imaging is the study of choice in pregnant patients when compression-graded ultrasound results are nondiagnostic.[8,102,103] In the first prospective, blinded study of MRI in appendicitis, Cobben et al demonstrated a sensitivity of 100% and a specificity of 98% for the diagnosis of acute appendicitis. In this study, 138 patients with suspected appendicitis were referred for ultrasound followed by noncontrast-enhanced MRI. Positive cases were confirmed by histologic finding of appendicitis, and patients with negative findings were followed for 2 years for possible subsequent appendicitis. In addition to the findings stated above, it was determined that the PPV of MRI was 98%, that the NPV was 98%, and that by incorporating MRI into the diagnostic process of these patients, the overall redirection of hospital resources would have produced a net savings of between approximately $600 and $800 per patient. In this study, the net savings represent the combined result of avoiding unnecessary appendectomies and unnecessary admissions for observation. This study found the sensitivity and specificity of ultrasound to be 88% and 99%, respectively.[104] Other studies have also demonstrated an advantage

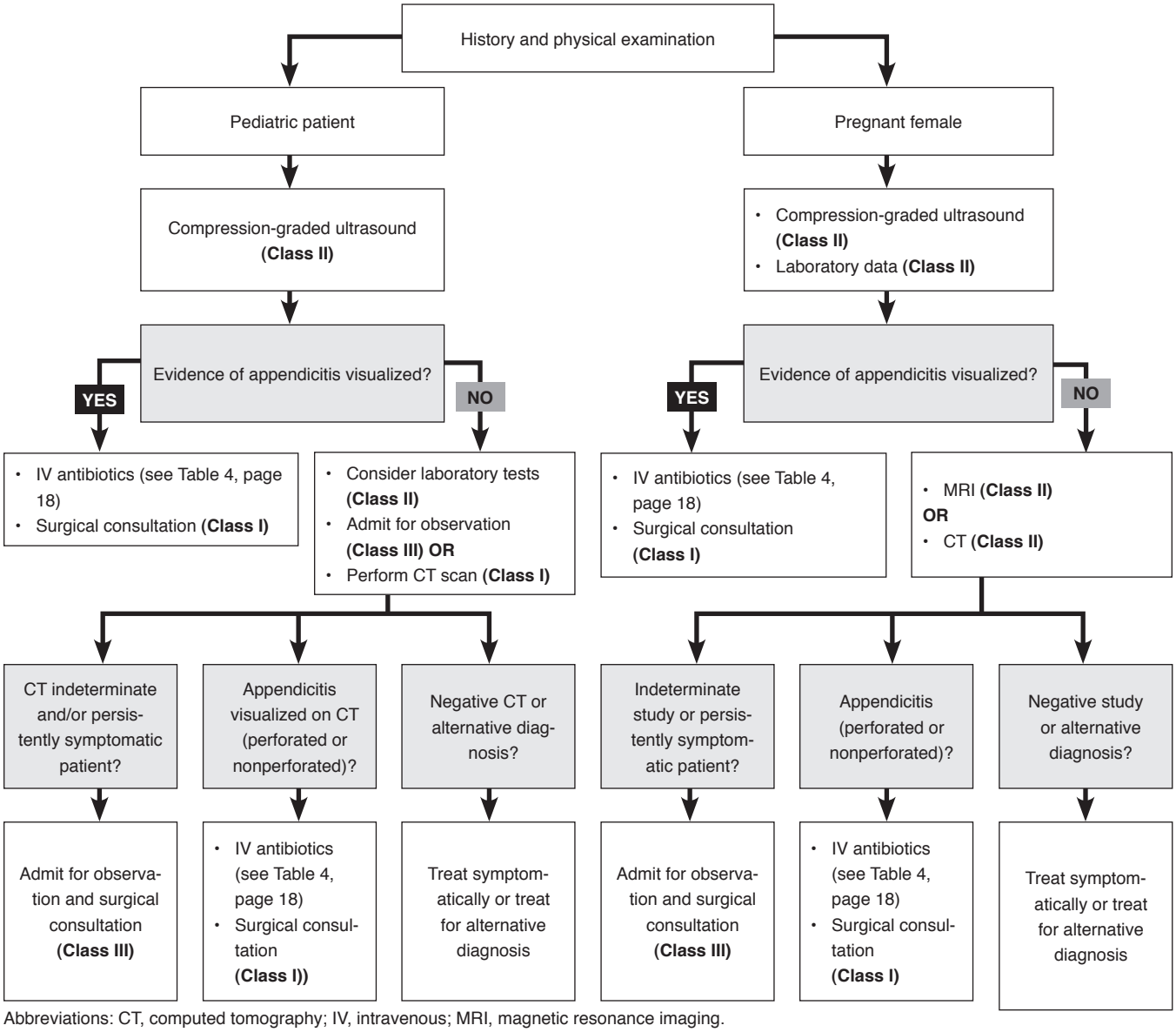
Clinical Pathway For Diagnosis Of Appendicitis In Adult, Nonpregnant Patients



Abbreviations: CRP, C-reactive protein; CT, computed tomography; IV, intravenous; RLQ, right lower quadrant; WBC, white blood cell.

For class of evidence definitions, see page 15.

Clinical Pathway For Diagnosis Of Appendicitis In Pregnant And Pediatric Patients



Abbreviations: CT, computed tomography; IV, intravenous; MRI, magnetic resonance imaging.

Class Of Evidence Definitions

Each action in the clinical pathways section of *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
- Non-randomized or retrospective studies: historic, cohort, or case control studies
- Less robust RCTs
- 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

Significantly modified from: The Emergency Cardiovascular Care Committees of the American Heart Association and representatives from the resuscitation councils of ILCOR: How to Develop Evidence-Based Guidelines for Emergency Cardiac Care: Quality of Evidence and Classes of Recommendations; also: Anonymous. Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. Part IX. Ensuring effectiveness of community-wide emergency cardiac care. *JAMA.* 1992;268(16):2289-2295.

of MRI over ultrasound in the ability to diagnose appendicitis accurately.[105,106]

The MRI criteria for diagnosing appendicitis are: (1) appendiceal diameter > 7 mm, (2) appendiceal wall thicker than 2 mm, (3) signs of inflammation adjacent to the appendix, such as fat stranding or phlegmon formation, or (4) presence of an abscess.[107,108]

Oral contrast is optional in abdominal MRI scans performed to rule out appendicitis, and whether it is administered depends on individual institutional protocol. If oral contrast is administered, it should be mixed with barium so that if the MRI proves to be nondiagnostic, one may proceed to CT without delay. Intravenous gadolinium-based contrast is not necessary to rule out appendicitis.[108] Gadolinium administration is contraindicated in pregnancy or in patients with renal insufficiency with a glomerular filtration rate < 30.[107,109]

When compared with ultrasound, MRI has the advantage of not being operator-dependent and is more useful than ultrasound in patients who are obese, have a retrocecal appendix, are pregnant, have a gaseous abdomen, or have a high likelihood of an alternative diagnosis. When compared with CT, MRI has the advantage of preventing patient exposure to ionizing radiation and does not require PO contrast, thereby expediting patient care. The disadvantages of MRI are its limited availability, increased propensity for motion artifact, higher cost, longer study times, and need for a radiologist that is proficient in MRI to be available to interpret the study (since most surgeons are uncomfortable interpreting MRI for appendicitis).[103] According to ACR Appropriateness Criteria® for suspected appendicitis (2010), despite a number of studies demonstrating high sensitivity and specificity for MRI, it is not recommended for appendicitis except in pregnant patients with a nondiagnostic ultrasound. The guideline authors do not believe that there is enough experience with MRI in appendicitis to warrant its recommendation at this time; however, in these guidelines they expressed hope that as MRI becomes increasingly available, further studies would elucidate MRI's role as a powerful tool for diagnosing appendicitis without exposure to ionizing radiation.[88]

Scoring Systems In Appendicitis

In an effort to aid in the effective diagnosis and management of acute appendicitis and decrease the rate of negative appendectomies, a number of clinical scoring systems have been developed that combine the most discriminative signs and symptoms of acute appendicitis.[110-114] The Alvarado scoring system, or MANTRELS score, which was first described in 1986, is the most well-known, and has performed sufficiently in validation studies when compared to other scoring systems.[110,112] In his retrospective analysis of 305 patients hospitalized with abdominal pain suggestive of acute appendicitis, Alvarado reviewed clinical and laboratory findings of patients who underwent appendectomy and were found to have either the presence or absence of postoperative histologic evidence of acute appendicitis.[110] From this analysis, Alvarado constructed a constellation of 3 symptoms (pain migration, anorexia, and nausea/vomiting), 3 physical signs (tenderness, rebound pain, and elevation of temperature), and 2 laboratory findings (leukocytosis and "left shift") that appeared to be useful in the clinical diagnosis of acute appendicitis. A point value was assigned to each diagnostic finding. Likelihood of appendicitis was based on the sum total of points for the patient.

Whether the Alvarado score can be used to predict which patients require admission and which can be safely discharged is debatable. Chan et al performed a recent prospective study of 175 consecutive patients who presented to the ED with suspected appendicitis to assess whether the Alvarado score can be used by emergency clinicians as a criterion for admission to the hospital. In their patient population, none of the 56 patients with an Alvarado score of 4 or less had appendicitis. They concluded that if this had been used as the admission criterion, 34 patients who were admitted could have been observed as outpatients and the admission rate would have been reduced by 20%.[115] This study, however, only included a follow-up period of 24 hours, and it is unknown what percentage of these patients later went on to develop worsening symptoms of appendicitis more than 24 hours later that may have required surgical intervention. Furthermore, in several other studies, a low Alvarado score did not reliably exclude appendicitis. Gwynn found that 12 of 143 patients with appendicitis (8.4%) had Alvarado scores below 5 and that patients in extremes of age (60-80 and 0-10) were misdiagnosed more frequently.[113] The data by Pouget-Baudry et al demonstrated that 23 of 55 patients (41.8%) with Alvarado score < 4 were ultimately diagnosed with appendicitis.[114] Yildirim et al found that 13 of 18 patients (72%) with Alvarado scores between 1 and 4 ultimately had appendicitis.[116] Therefore, using low Alvarado scores (< 4) as a criterion for discharge in patients with suspected appendicitis should be done with extreme caution and cannot be recommended given the current evidence.

The pediatric population deserves special consideration with respect to scoring systems for acute appendicitis due to this group's propensity to present atypically and a decreased desire on behalf of clinicians to expose these patients to ionizing radiation via CT scans. In a recent prospective study over a 5-year period of 1170 children aged 4 to 15 years with abdominal pain suggestive of acute appendicitis, Samuel compared 2 groups of patients—734 patients with appendicitis and 436 patients without appendicitis—and, using a stepwise multiple logistic regression analysis, developed the Pediatric Appen-

dicitis Score (PAS), which is comprised of 8 independent variables, all highly statistically significant ($P < .001$), that were more consistent with a diagnosis of acute appendicitis.[117] Similar to the Alvarado score, Samuel constructed a constellation of 3 symptoms (pain migration, anorexia, and nausea/vomiting), 3 physical signs (tenderness in RLQ, cough/percussion/hop tenderness, and elevation of temperature), and 2 laboratory findings (leukocytosis and polymorphonuclear neutrophilia) that appeared to be useful in the clinical diagnosis of acute appendicitis in children. A point value was assigned to each diagnostic finding. Samuel concluded that a score of ≤ 5 is not consistent with a likely diagnosis of appendicitis, whereas a score of ≥ 6 is compatible with the diagnosis of appendicitis, and scores of 7 to 10 indicate a high probability of appendicitis. Using a cutoff of ≥ 6, the PAS in his patient population had a sensitivity of 100%, specificity of 92%, PPV of 96%, and NPV of 99%. A recent prospective observational study by Schneider et al sought to validate the performance of the Alvarado and Samuel/PAS scoring systems in a cohort of pediatric patients (median age 11.9 years) with suspected appendicitis.[118] The authors demonstrated that although both the Alvarado and Samuel/PAS scoring systems provide some useful clinical information, both systems had overall poor diagnostic utility when used as the sole method for determining the need for surgery in cases of children with suspected appendicitis. A systematic review by Bundy et al involving pooled prospective studies focusing on children with appendicitis reported a similarly poor diagnostic utility of an Alvarado score.[119] Therefore, although clinical scoring systems may add useful clinical information in pediatric cases of acute appendicitis, these patients would likely benefit more from earlier surgical consultation and noninvasive imaging techniques such as appendiceal ultrasound than their adult counterparts (see page 12).

In a recent well-designed multicenter prospective study of 545 consecutive patients, Andersson and Andersson were able to construct (n = 316 patients, 46% men, 54% women, mean age 25.9 years) and validate (n = 229 patients, 46% men, 54% women, mean age 23.4 years) a user-friendly clinical scoring system based on prospectively collected data from patients admitted for suspected appendicitis and compare its performance to the Alvarado clinical scoring system.[111] Eight variables remained in their final model, and the simplified integer-based score ranged from 0 to 12 points. **(See Table 3.)** The authors demonstrated that the simplified score had a better discriminating capacity for all appendicitis when compared with the Alvarado score, with a receiver operating characteristic (ROC) area of 0.93 versus 0.88 ($P = 0.0007$).The scoring system presented in their study was able to correctly classify 73% of nonappendicitis patients to the low-probability group and 67% of patients with advanced appendicitis to the high-probability group with high accuracy in their patient population. Only 37% of the patients remained in the indeterminate group. This compared favorably with the Alvarado score, which offered 61%, 40%, and 48% for the corresponding results. Thus, this represents a novel, high-performing scoring system that takes into consideration recent advances in our understanding of the inflammatory response (ie, the role of PMN count, WBC predominance, and CRP concentration) in the context of acute appendicitis since the time of Alvarado's original article in 1986. The purpose of Andersson and Andersson's Appendicitis Inflammatory Response Score is to risk stratify patients with possible appendicitis in order to reduce unnecessary imaging, provide a tool for clinicians to safely discharge low-risk patients home, and help identify those that might benefit from early surgical intervention without the need for further imaging. Nonetheless, more prospective validation studies must be performed on different patient populations to confirm the score's external validity before it can be recommended for widespread use.

Treatment

The treatment of acute appendicitis in the ED consists of 3 major aspects: 1) supportive care, 2) antibiotic therapy, and 3) definitive treatment as

Table 3. Appendicitis Inflammatory Response Score[111]

Variables		Score
Vomiting		1
Pain in right inferior fossa		1
Rebound tenderness or muscular defense	Light Medium Strong	1 2 3
Body temperature > 38.5˚C (101.3˚F)		1
Polymorphonuclear leukocytes	70%-84% ≥ 85%	1 2
WBC count	10.0-14.9 ≥ 15.0	1 2
CRP concentration	1-4.9 mg/L ≥ 5 mg/L	1 2
Sum		**(0-12)**

Sum 0–4 = Low probability. Outpatient follow-up if unaltered general condition.

Sum 5–8 = Indeterminate group. Inhospital active observation with rescoring/imaging or diagnostic laparoscopy according to local traditions.

Sum 9-12 = High probability. Surgical exploration is proposed.

Abbreviations: CRP, C-reactive protein; WBC, white blood cell.

decided upon by a surgical consultation. Supportive care is to be tailored to the patient's symptoms. Most often, patients with appendicitis should receive IV fluids (lactated Ringer or normal saline), should receive symptomatic treatment (eg, antiemetics and analgesia), and should remain NPO. Choice of analgesia will depend on the personal preference of the provider; however, IV opiates are often considered first-line treatment in possible appendicitis cases.[120] Multiple prospective randomized trials and a Cochrane Database review on analgesia in patients with acute abdominal pain have all concluded that opiates improve patients' cooperation, relieve their pain, and do not mask the physical signs of appendicitis. Unless contraindicated, it is unacceptable to withhold analgesia from patients presenting with acute abdominal pain.[121-124] In the rare case of acute appendicitis causing septic shock, treatment is guided by the Surviving Sepsis Campaign International Guidelines of Severe Sepsis and Septic Shock.[125]

Administer antibiotics promptly upon making the diagnosis of appendicitis.[126] A Cochrane database review of 45 studies involving 9576 patients found that antibiotic administration in appendicitis reduces the incidence of both postoperative wound infection and intra-abdominal abscess formation when compared to placebo.[127] Interestingly, these studies demonstrated no difference in the postoperative histologic findings of appendicitis in the antibiotic versus placebo groups. **(See Table 4 for antibiotic recommendations.)**

A few points from the 2009 Surgical Infection Society/Infectious Diseases Society guidelines regarding management of complicated intra-abdominal infections are important to review. Neither ampicillin-sulbactam nor cefotetan or clindamycin are recommended for intra-abdominal infections due to high resistance rates of community-acquired *Escherichia coli* and *Bacteroides fragilis,* respectively. Aminoglycosides are not recommended due to the fact that there are other antibiotics that are at least as efficacious but are less toxic. Coverage for methicillin-resistant *Staphylococcus aureus* (MRSA) is not recommended unless there is a healthcare-associated intra-abdominal infection in a patient that is known to be colonized with MRSA. One must be aware of the increased rate of quinolone resistance of *E coli* in many regions, and consequently, quinolones should not be used in appendicitis unless the clinician's institution's antibiograms have a > 90% susceptibility of *E coli.* Blood cultures are not recommended in cases of appendicitis unless the patient is toxic, septic, or immunocompromised.[126]

Recommendations on definitive management for acute appendicitis depend on the presence or absence of complications. Treatment for nonperforated appendicitis with a well-circumscribed abscess is nonoperative and consists of IV antibiotics and percutaneous drainage. The management recommendations for nonperforated appendicitis without abscess or perforated appendicitis is urgent operative intervention.[126]

Conservative management for appendicitis without abscess has become a controversial topic recently. Conservative therapy consists of hospitalization for IV antibiotics rather than emergent surgical intervention. Although Dr. Coldrey published a protocol in 1956 involving exclusive antibiotic treatment of appendicitis lasting more than 24 hours with great personal success, only in the last 20 years has the idea of conservative treatment been highlighted by multiple prospective trials and meta-analyses. The benefit of conservative treatment is rooted in the fact that there is significant perioperative morbidity associated with an appendectomy. [28,135] On average, the rate of complications from appendectomies is approximately 4.6% and includes small bowel obstruction, wound infection, abscess formation,

Table 4. Antibiotic Treatment Of Acute Appendicitis (All Types: Nonperforated, Perforated, And With Abscess)

Patient Group	Single-agent Regimen	Multi-agent Regimen
Pediatric patients (community-acquired)	Ertapenem, meropenem, imipenem-cilastatin, ticarcillin-clavulanate, or piperacillin-tazobactam	Metronidazole in combination with 1 of the following: ceftriaxone, cefotaxime, cefepime, or ceftazidime
Adult patients (community-acquired)	Cefoxitin, ertapenem, moxifloxacin, tigecycline, or ticarcillin-clavulanic acid	Metronidazole in combination with 1 of the following: cefazolin, cefuroxime, ceftriaxone, cefotaxime, ciprofloxacin, or levofloxacin**
Adults with high-risk features* or healthcare-acquired illness	Imipenem-cilatatin, meropenem, doripenem, or piperacillin-tazobactam	Metronidazole in combination with 1 of the following: cefepime, ceftazidime, ciprofloxacin, or levofloxacin**

*High-risk features include any of the following:

- advanced age, end stage organ dysfunction, or poor nutritional status/hypoalbunemia
- immunocompromised state
- diffuse peritonitis, APACHE > 15 (ie, high-severity of illness), or delay in initial intervention of > 24 hours

**Floroquinolones are only to be used in institutions with *E coli* with > 90% susceptibility to floroquinolones.

and adhesions.[26,128] Although more recent studies have discerned a decreased rate of complications in the conservative treatment group with no increase in length of stay, the data have also found that within 1 year of discharge, between 14% and 29% of patients have recurrent appendicitis requiring an interval appendectomy.[128-132] There has been much debate regarding these studies and their inability to distinguish which patients would benefit most from conservative therapy and which patients will require emergent surgical intervention. Identifying patient characteristics that will help discern these 2 populations will direct future research on this topic.[26,128] Accordingly, the 2009 Infectious Diseases Society of America guidelines on intra-abdominal infections state that there is class B evidence supporting conservative treatment for nonperforated appendicitis in patients who have "marked improvement" in their clinical condition prior to their operation.[126] However, in current practice, the choice of conservative versus operative treatment is one that the consulting surgeon would make.

In both pediatric and adult nonperforated appendicitis, it has been demonstrated that inhospital delay of up to 12 hours between diagnosis and surgical intervention does not increase the likelihood of perforation.[133-140] There has been much debate and many conflicting studies regarding delaying a surgical intervention longer than this. Multiple studies have demonstrated that although inhospital delay of less than 12 hours does not affect perforation rates, patient delay in presenting to the diagnosing physician does increase the risk of perforation, and delay in seeking care is the most important risk factor for perforation.[133,137,141]

Special Populations

Pregnant Patients

Appendicitis is the most common nonobstetrical surgical emergency during pregnancy, occurring in 1 in 766 births.[4] Appendicitis is most common during the second trimester, with the distribution of appendicitis cases across trimesters as follows: first trimester (30%), second trimester (45%), and third trimester (25%).[4,142] Diagnosing appendicitis during pregnancy can be challenging, since symptoms and signs that are common in appendicitis also occur with frequency during regular gestation.[143] Anorexia, nausea, vomiting, abdominal pain, and a physiologic leukocytosis are examples of elements of both a normal pregnancy and a potential appendicitis. In one small retrospective study by Cunningham et al, the most common complaints in pregnant patients with appendicitis were abdominal pain, nausea, and vomiting, while physical findings included direct and rebound abdominal tenderness.[144] Appendicitis in pregnancy is a difficult diagnosis because in the first trimester, appendicitis is often mistaken for pelvic pathology and in the last 2 trimesters the appendix may be displaced by the gravid uterus.[11] Classic obstetrical teaching is that as the fetus grows, the uterus pushes the appendix superiorly. This was first demonstrated in 1932 by Baer et al who performed barium studies on pregnant women and found that as the fetus develops, the uterus pushes the appendix up and relocates its tip superiorly in a counterclockwise direction. However, multiple studies have found that despite the possibility of upward displacement of the appendix, pain in the RLQ is still the most common presenting complaint in gravid patients with appendicitis in all trimesters of pregnancy. This complaint should be taken seriously, especially when this pain is new or different from previous episodes of pain that the patient has been accustomed to during her pregnancy.[4,143,144,146]

With appendicitis, both delayed diagnosis as well as laparotomy (both positive and negative) increase risk of premature labor and potential fetal loss.[144] As a result, accuracy and efficiency are vital in order to optimize diagnosis in those with equivocal presentations and to reduce false positives in those without appendicitis. Therefore, in addition to a thorough history and physical examination, utilizing ultrasound and MRI in pregnant patients is vital to effective, efficient, and safe care.[102]

The ACR recommends that if imaging of the abdomen is required during the evaluation of a gravid woman, the first choice should be to use nonionizing methods such as ultrasound or MRI. Graded compression ultrasound has been recommended as the initial imaging test of choice to exclude appendicitis in pregnancy.[88,148] If the ultrasound is positive for appendicitis, no further confirmatory tests are required and the patient may proceed to surgery.[97,147] If the ultrasound is nondiagnostic, it should be followed by an MRI, if available.[88,148] Magnetic resonance imaging is both accurate for appendicitis and is excellent for finding alternative diagnoses in pregnant patients (with the exception of ovarian torsion, which is best visualized with ultrasound).[149] In a retrospective study of 51 consecutive pregnant patients with suspected appendicitis, Pedrosa et al demonstrated that MRI with PO contrast had a high sensitivity (98%-100%) and specificity (92%-93%) for appendicitis in pregnancy.[150] A meta-analysis by Blumenfield et al involving 5 studies and 229 patients determined MRI to be useful in appendicitis during pregnancy. The authors determined MRI to have a sensitivity of 90% to 95%, a specificity of 98% to 99%, a PPV of 86% to 90% and a NPV of 99%.[151] Magnetic resonance imaging has been used to evaluate gravid patients for over 20 years, and although theoretical safety issues related to exposure to various types of magnetic fields, heating effects, and effects of acoustic noise do exist, all studies to date indicate that there is no threat of significant injury or harm to

the fetus at magnetic field strengths used for abdominal MRI.[79,98,152] The ACR 2007 statement on MRI in pregnancy is summarized as follows: (1) MRI may be used in pregnant patients in any trimester if both the primary physician and radiologist consider the test necessary and (2) the patient signs a written consent attesting to understanding the theoretical risk, benefit, and alternative diagnostic options.[98,109] Gadolinium contrast is category C in pregnancy and should not be administered when looking for appendicitis.[98]

If ultrasound and MRI are unavailable, CT can be used in pregnant patients who require imaging due to a potentially life-threatening illness, particularly if transfer to a center with MRI is not feasible. Computed tomography for appendicitis in pregnancy should be used in consultation with the obstetrician, surgeon, and radiologist. A fetus is most at risk for spontaneous abortion, birth defects, and neurologic deficits between 2 and 15 weeks gestation.[153] Research by Hurwitz et al using

Risk Management Pitfalls For Appendicitis (Continued on page 21)

1. **"The 14-year-old male patient wanted a hamburger and french fries. There was no way that he had appendicitis!"**
   Two mistakes were made. First, no single symptom or sign can either diagnose or exclude appendicitis. Multiple aspects of history, physical examination, and laboratory testing must be used to assist in risk stratifying patients. Second, anorexia has poor positive and negative predictive value in appendicitis.

2. **"The radiologist read the CT as negative, but the patient still had abdominal pain, so I diagnosed her with gastroenteritis. She returned with perforated appendicitis the next morning."**
   Tip appendicitis is a well-studied reason for false-negative CT readings and is something to always consider in the patient that is persistently symptomatic. The appendix must be visualized from its base at the cecum all the way to its tip for any wall thickening, dilation, or associated inflammatory changes.

3. **"The urinalysis was positive for RBCs and WBCs, so I discharged the patient with a UTI. Later that night, my associate told me she returned to the ED vomiting and appeared ill, and the CT demonstrated appendicitis."**
   An inflamed appendix can abut the ureter and result in ureteral inflammation with nonspecific urinalysis findings. Urinalysis findings of > 30 RBCs per high-powered field or > 20 WBCs per high-powered field are more consistent with a UTI.

4. **"A 22-year-old male with no prior surgical history presented vomiting, with diffuse abdominal pain. The x-ray demonstrated a small bowel obstruction, so I placed a nasogastric tube and the patient was admitted to the surgical floor. The patient became hypotensive and septic just before heading up to the floor."**
   Perforated appendicitis is a known cause of small bowel obstruction. Peritoneal inflammation results in ileus and obstruction. The emergency clinician should have heightened suspicion when the history and physical examination are more consistent with appendicitis and/or there are no risk factors for bowel obstruction, such as prior abdominal surgeries.

5. **"A 16-year-old male presented with RLQ pain, rebound, and vomiting, so my colleague in the ED consulted surgery promptly. The surgeon requested that labs be drawn and said that she would be down to see him shortly. My colleague said that lab tests are of no value in diagnosing appendicitis and then proceeded to argue the utility of these tests with the consulting surgeon."**
   White blood cell count, CRP level, and elevated PMN count are of some utility in diagnosing appendicitis, according to the ACEP Clinical Policy on patients with suspected appendicitis. Although an elevated WBC count or elevated CRP level alone is of little value, the combination of both WBC count and CRP level was found to have excellent positive and negative predictive values.

6. **"A 3-year-old female presented with diarrhea over the last 8 hours. The abdomen was firm and she grimaced on abdominal palpation. She was afebrile and appeared well otherwise. I sent the child home, but she returned 4 hours later with fever and peritonitis."**
   There is no easy answer in children with appendicitis, particularly those who are very young. They present very atypically as a rule, often have no pyrexia or peritoneal signs, can compensate quite well hemodynamically, and cannot offer a reliable history. Furthermore, diarrhea is a common presenting complaint. Keep a very high clinical suspicion for appendicitis in children, particularly infants, and any abnormality that is not typical must be

Anthropomorphic Phantoms (ie, models that detect radiation) demonstrate that although the levels of radiation that a fetus experiences during an abdominal CT are unlikely to result in neurologic defects, the level of radiation a fetus experiences could theoretically double the risk of childhood cancer.[154] Although nonionizing examinations are preferred, if one must perform an abdominal CT on a pregnant patient, it is crucial to first discuss the risks, benefits, and alternatives with the patient and next discuss the case with the radiologist to optimize the CT protocol to minimize fetal radiation exposure.[98,153] Intravenous iodinated contrast material used in CT is classified as a category B drug by the United States Food and Drug Administration and is generally accepted as safe. Iodine does cross the placenta, which allows fetal exposure; however, this is believed to be short-lived. It is recommended that any infant exposed to iodinated contrast during gestation have a thyroid function test in the

Risk Management Pitfalls For Appendicitis (Continued from page 20)

taken seriously. Have a low threshold for serial abdominal examinations and possible admission for observation, and consider laboratory testing when in doubt. In addition, the symptom of "diarrhea" is often overstated by parents and always needs to be clarified by the clinician.

7. **"A 35-year-old female presented with suprapubic pain and fever. I performed a pelvic examination and found cervical motion tenderness, so I treated for PID and discharged home. The next morning as I came in to work, I saw the same patient being wheeled to the operating room for an appendectomy."**
Cervical motion tenderness is a nonspecific finding and can be seen in peritoneal inflammation of any cause. Be sure to perform a complete history and physical examination on every patient, including a good social/sexual history to aid in guiding your diagnostic work-up.

8. **"A 42-year-old male presented with right flank pain and vomiting, with a small amount of blood on his urinalysis. He improved with nonsteroidal anti-inflammatory drugs and antiemetics, had a renal ultrasound that was negative for hydronephrosis, and was discharged home. He returned febrile and with peritoneal signs."**
The appendix can have a retroperitoneal location in approximately 7% of patients, which may present atypically as right flank pain.

9. **"A 22-week pregnant female presented with RLQ pain over the last 8 hours that was worse than her typical 'pregnancy pains.' I suspected appendicitis, so I ordered an ultrasound, which was nondiagnostic. There is no MRI at our facility. The surgeon told me to call gynecology, and the gynecologist told me to call the surgeon. I sat on the patient for hours until she started spiking fevers and looking ill. The surgeon finally came in to assess the patient, who then had peritoneal signs. She had a miscarriage on post-op day 1, a prolonged hospital stay, and increased morbidity."**
If you need a CT scan on a pregnant female, then get one! The risk of radiation to the fetus does not outweigh the risk of missing the diagnosis of a serious intra-abdominal infection in this patient (especially at 22 weeks' gestation). A fetus is at greatest risk of radiation between 2 to 15 weeks' gestation; however, even at this stage, if a patient truly requires a CT scan, then it is prudent to get one. A frank discussion of risks and benefits must be had with the patient, and the case should be reviewed with the radiologist in order to develop a protocol to minimize radiation to the fetus. Please note that "just take the patient to the operating room" is not the answer, since there is greater risk of miscarriage from a negative appendectomy than from a CT scan.

10. **"An 18-year-old male with vomiting, midepigastric pain, and mild RLQ tenderness had leukocytosis and a mildly elevated CRP level. It was an equivocal case, so I ordered a CT and surgery consult. The surgeon demanded that no analgesia be administered so he could get an accurate examination on the patient, but he was in surgery and wouldn't be down for 90 minutes or so. The patient writhed in pain for the next 2 hours awaiting completion of his CT scan and surgical consultation (and our Press Ganey scores tanked)."**
Analgesic medication has been demonstrated by multiple well-designed prospective studies to not affect the accuracy of a clinician's abdominal examination. In the absence of contraindications, withholding analgesia from patients with acute abdominal pain is unacceptable.

first week of life, which is standard practice in the United States. Of note, both iodinated and gadolinium contrast are both considered safe for patients who are breastfeeding.[98]

Pediatric Patients

Appendicitis is the most common acute surgical emergency during childhood, with an incidence of approximately 2 to 4 per 1000 infants. Although it may occur at any age, it is most common above the age of 5 years.[79] In pediatric patients, atypical presentations combined with the inability to elicit an accurate history in young children leads to delayed diagnosis, possible increased morbidity, and resultant higher rates of appendiceal perforation (which have been reported to be almost double the perforation rate as the general population).[5,155,158] Infants, in particular, are more likely than older children to present with symptoms such as recent respiratory tract infection, anorexia, vomiting, irritability, fever, and the absence of abdominal pain.[159] Atypical presentations in children are very common. When compared with young and middle-aged adults, children have an even more variable presentation. A prospective study by Becker et al involving patients with suspected appendicitis between the ages of 3 to 21 years had the following atypical findings: 83% without pyrexia, 31% to 52% with no peritoneal signs, 50% with lack of pain migration, and 32% with the point of maximal tenderness outside the RLQ.[160] A retrospective study by Rothrock et al of patients younger than 13 years who were ultimately diagnosed with appendicitis found that the most common misdiagnoses in these patients were gastroenteritis and upper respiratory tract infection. In this study, the patients that were misdiagnosed were more likely to be younger and have symptoms that included constipation, diarrhea, dysuria, upper respiratory symptoms, vomiting prior to pain, and lethargy or irritability.[161]

Diarrhea alone does not exclude the possibility of appendicitis. In one study, diarrhea was present in up to 17% of pediatric patients with appendicitis, and an epidemiologic analysis from Sweden postulates that enteritis may predispose children to appendicitis, possibly via lymphoid hyperplasia and appendiceal obstruction.[162,163] Sakellaris et al performed a retrospective study in patients under 5 years old with suspected appendicitis and found 73% to have advanced appendicitis with either perforation or abscess formation, which is a testimony to the difficulty in making this diagnosis in young children and the need for a high clinical suspicion in this subpopulation.[164] Clinical assessment alone, without supplemental imaging, in children has been associated with a negative appendectomy rate of 13% to 25%.[157,165,166] Obtaining appropriate imaging has decreased this rate to 3% to 7%.[60,167] Therefore, a high clinical suspicion (especially in infants) and low threshold for ordering imaging in children with possible appendicitis is key to making an accurate and timely diagnosis. Nevertheless, the diagnosis of appendicitis in this population is very difficult, and one must balance the risk of radiation with the benefit of early diagnosis in very young children who often present with perforated appendicitis (which is difficult to visualize using ultrasound). A frank discussion with parents regarding the decision-making process, the risks associated with CT, and explicit discharge instructions for those who go home is always advised to help clarify expectations and should be well-documented in the patient's record. In equivocal cases with a nondiagnostic ultrasound when the emergency clinician is too concerned to discharge the patient home, admission to the hospital for serial abdominal examinations and close monitoring is always an option to consider.

The initial imaging modality of choice in the pediatric population should be graded compression ultrasound.[10,79,88] Rosendahl et al published a review that found that ultrasound demonstrated a sensitivity between 87% and 95% and a specificity between 85% and 95% in the pediatric population.[79] The ACR Appropriateness Criteria® for suspected appendicitis (2010) recommends that if the ultrasound is interpreted as nondiagnostic (ie, no appendix is visualized), it should be followed by a CT enhanced with both IV and enteric (PO or PR) contrast.[88] Note that these guidelines state – and multiple studies support – that in pediatric patients one might consider a focused RLQ/pelvic CT rather than a complete abdominal study for patients in whom appendicitis is high on the differential.[79,87,88]

Although MRI does not involve patient exposure to ionizing radiation, the disadvantage of MRI is the need for the child to be still for a prolonged period of time, thereby often necessitating sedation in younger children to reduce motion artifact. This need for sedation is likely the reason that there have not been many studies on MRI in pediatric appendicitis and its use is still limited in clinical practice.[79] However, Hörmann et al published a prospective study on the use of MRI in a group of 45 children aged 7 to 16 years who were referred due to a high clinical suspicion of appendicitis. All 45 children had histologically confirmed nonperforated appendicitis, and MRI revealed appendicitis in 100% of these cases (100% sensitivity). Of note, no PO or IV contrast was administered and no sedation was needed in this group of children.[92] Nevertheless, ACR Appropriateness Criteria® (2010) state that there is not enough evidence to support the use of MRI as a diagnostic study of choice in children with suspected appendicitis.[88]

Disposition

Disposition will ultimately be determined by certitude of the diagnosis. Radiographic evidence of appendicitis requires prompt surgical consultation, antibiotic administration, and likely operative intervention. Alternatively, CT or MRI that is negative for any intra-abdominal pathology must be considered in the context of reassessment of the patient. If imaging is negative but the patient has persistent pain, intractable vomiting, ill appearance, or unstable vital signs, then admission for close observation and surgical consultation may be warranted. One must remember that there are both technical and practical reasons for false-negative interpretations on imaging, including tip appendicitis, lack of intra-abdominal fat resulting in decreased periappendiceal inflammatory changes, enteric contrast not traveling to the level of the cecum, and reader error. However, if imaging is negative and the clinical status of the patient is improved, then it is safe to discharge the patient home with strict discharge instructions.

If no imaging is performed, laboratory data are non-contributory, history and physical examination are non-diagnostic, serial examinations are benign, and the patient's symptoms have improved, then it is reasonable to send the patient home with strict instructions, provided that they are reliable and will return if necessary. If there is any question as to the clinical status of these patients or their reliability, then the alternative would be to admit them for observation and serial abdominal examinations.

The final possibility that emergency clinicians may be confronted with is a "classic case" of appendicitis in a young male patient where the emergency clinician is certain of the diagnosis. This case should be discussed with the attending surgeon, and a decision to either proceed to laparoscopy or to obtain further imaging should be made jointly.

Summary

Appendicitis is one of the most common surgical emergencies in patients of all ages, and it remains a common cause of malpractice claims against emergency clinicians despite the introduction of CT. The variability of presentation in appendicitis is directly related to the varied anatomical location of the appendix and its visceral innervation and may manifest as right flank pain, LLQ pain, periumbilical/midepigastric pain, or RLQ pain. In addition to its varied location, other factors contribute to the difficulty in diagnosing appendicitis. The proximity of the appendix to the pelvic organs in females accounts for the greater risk of misdiagnosis and higher negative appendectomy rate in women. Furthermore, extremes of age contribute to the difficulty in diagnosis due to the fact that the very young are unable to offer reliable history and examination findings, the elderly (as in many other disease processes) present atypically as a result of increased comorbidities, and in both populations, appendicitis is not realized as a likely diagnosis because of its relative infrequency.

The most useful symptoms that assist in diagnosis of appendicitis are migration of pain to the RLQ, presence of pain in the RLQ, and presence of pain prior to vomiting. The most useful signs include RLQ tenderness and rigidity. Despite traditional teaching, there is utility in analysis of serum inflammatory markers to aid in the diagnosis of appendicitis. The greatest benefit is attained through combining WBC count and CRP level. In all but the most obvious cases of appendicitis, additional value is obtained via advanced imaging techniques. In nonpregnant adults, the initial imaging modality of choice is CT. Although CT without contrast is an acceptable alternative according to ACEP, it is still the preference of the ACR that patients undergo CT using both IV and enteric contrast. In pregnant patients and children, the initial study of choice should be ultrasound. If the ultrasound is nondiagnostic (ie, the appendix is not visualized), then one may proceed with an MRI in pregnant females and a CT in children. Focused RLQ CT scans are acceptable in children in whom suspicion for an alternative diagnosis is low.

Once the diagnosis of appendicitis is made, the standard of care is to provide antibiotics to the patient promptly. The choice of antibiotics is made based on the acuity of the patient, the presence of immune deficiency or organ dysfunction, and whether or not the patient has community or nosocomial risk factors.

It has been-well studied and is generally accepted that analgesic medication does not change a patient's examination findings and, therefore, there is no valid reason to withhold analgesia from a patient with abdominal pain, provided there are no other contraindications.

Case Conclusions

The young boy was found to have a WBC of 16, a PMN count of 87%, and a CRP level of 8. You realized that by using the PAS, this patient had a score of 9, which implies a high likelihood of appendicitis. This prompted you to call the surgical consult, who requested the patient receive a graded compression ultrasound of the RLQ. The ultrasound demonstrated a noncompressible 10-mm tubular structure. You promptly started the patient on cefotaxime and metronidazole, and the surgeon whisked him off to surgery.

The patient in the second case presented very atypically. You were going to send her home with a UTI, but luckily she started vomiting while in the ED and then

spiked a fever. A CT with rectal contrast demonstrated an enlarged, necrotic appendix, and the patient underwent laparoscopic appendectomy without complication. Once again, you were reminded that elderly patients with appendicitis present atypically, and you must have a high clinical suspicion and a low threshold to order imaging in this patient population. Furthermore, urinalysis may demonstrate nonspecific inflammatory signs in an appendicitis patient of any age.

The last case was a "classic" case of appendicitis, and you felt good that you made the diagnosis. The only problem was the fact that you felt that your patient was not getting the treatment he needed in a timely fashion. Studies have demonstrated that an inhospital delay of up to 12 hours is not associated with increased complication rates (and surgeons know this). Next time this happens, relax, and know that your patient will likely be just fine!

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 as the type of study and the number of patients in the study, will be included in bold type following the reference, where available.

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1. **Females have almost double the lifetime risk of undergoing an appendectomy as males.**
   a. True
   b. False

2. **Which patient population has the highest mortality rate associated with appendicitis?**
   a. Ages ≤ 5 years
   b. Ages 6-17 years
   c. Ages 30-40 years
   d. Ages ≥ 65 years

3. **All of the following are risk factors for acute appendicitis EXCEPT:**
   a. African American race
   b. Male gender
   c. Presentation in summer months
   d. Young age

4. **All of the following are common causes of appendiceal luminal obstruction EXCEPT:**
   a. Fecaliths
   b. Fecal stasis
   c. Lymphoid hyperplasia
   d. Blood

5. **The average time course from the onset of pain to appendiceal perforation is < 12 hours.**
   a. True
   b. False

6. **Which of the following symptoms elicited on history is LEAST useful to diagnose acute appendicitis?**
   a. Presence of RLQ pain
   b. Presence of pain prior to vomiting
   c. Migration of pain from the epigastrium to the RLQ
   d. Anorexia

7. **Which sign on physical examination is MOST predictive in diagnosing appendicitis?**
   a. RLQ tenderness and rigidity
   b. Presence of a Rovsing sign
   c. Presence of a psoas sign
   d. Temperature above 38.3°C (101°F)

8. **All of the following abnormal laboratory findings can be found on a urinalysis of a patient with appendicitis, attributed to an inflamed appendix abutting the ureter, EXCEPT:**
   a. Greater than 20 leukocytes per high-powered field
   b. Less than 30 RBCs per high-powered field
   c. Pyuria
   d. Bacturia

9. **Which of the following contributory data offer the most predictive value for diagnosing acute appendicitis?**
   a. Leukocytosis alone (WBC > 10)
   b. Leukocytosis and PMN 80% to 84.9%
   c. CRP > 8
   d. WBC > 10 and CRP > 8

10. **Treatment for all patients with acute nonperforated appendicitis must include:**
    a. Witholding analgesia
    b. Immediate antibiotics
    c. Blood cultures
    d. Surgery within 12 hours

Evidence-Based Diagnosis And Treatment Of Torsion Of The Spermatic Cord In The Pediatric Patient

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The incidence of acute torsion of the spermatic cord (TOSC) has been estimated to be 4.5 cases per 100,000 population. Others have cited an annual incidence of 1 in 4000 males under 25.2 While not especially common in the emergency department (ED), these cases are important to the patient, the clinician, and the consultants who might be needed. Sorting out the etiology can be vexing. Doing so frequently involves not only examination but also imaging and consultation with surgery or urology colleagues. When faced with an acutely swollen and painful scrotum, the surgeon must decide quickly whether or not to explore the scrotum, and if a testicular torsion is found, choose between testicular salvage and removal. Both decisions can have consequences for the patient. The outcome for the patient is as dependent on the time elapsed from the onset of the attack, as it is on the decisions of the surgeon. This month's issue of Pediatric Emergency Medicine Practice *delves into the problem of the male with a possible TOSC. The authors examine existing literature to develop a strong strategy for clinicians that explains what to do and when to do it in the diagnosis and treatment of TOSC.*

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High-Risk Scenarios In Blunt Trauma: An Evidence-Based Approach

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Most injuries in the United States result from blunt mechanisms, including motor vehicle crashes and falls as well as from interpersonal violence. Patients who suffer severe blunt trauma typically experience a significant force vector, rapid deceleration, or both. Under these circumstances, multiple potentially life-threatening injuries are likely, requiring careful prioritization of diagnostic and therapeutic interventions. In the unstable patient with multisystem blunt trauma, a useful team strategy: (1) rapidly identifies the cause(s) of traumatic shock, (2) identifies and prioritizes "time-dependent" injuries in need of definitive therapy, and (3) orchestrates an immediate care plan that thoughtfully matches ongoing resuscitation with the identified injuries and the patient's clinical course. This issue of EMCC *will provide a logical "menu" for the rapid evaluation and management of traumatic shock. Three "high-risk" clinical scenarios will then be discussed: blunt aortic injury (BAI), pelvic ring fractures, and blunt abdominal trauma. These scenarios were chosen because of their lethality and call for complex decision making. The essentials of emergency department (ED) diagnosis and management will be reviewed for each.*

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