# Appendicitis

# 49

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> Diagnosis of appendicitis is usually not especially difficult.
> William Silen – Cope's Early Diagnosis of the Acute Abdomen 1979

> I doubt whether there is any disease which has symptoms of such variable degree as appendicitis. Everyone has seen children with negligible symptoms who, at operation, have had gangrene of the appendix. It is these mild cases so easily missed, which eventually make every clinician of experience eat his portion of fricasseed crow.
> Willis J. Potts – The Surgeon and the Child 1959

## Introduction

Appendicitis, or inflammation of the appendix, is the most common emergent surgical condition in children and accounts for approximately 10% of all pediatric emergency room visits [1]. While some considered it a vestigial organ, the appendix serves as a reservoir for normal intestinal microbiota and has the highest concentration of gut-associated lymphoid tissue in the intestine [1]. Despite its high incidence, appendicitis is the most frequently misdiagnosed surgical condition of the abdomen [2]. To minimize misdiagnosis and standardize care, several algorithms to both diagnose and treat appendicitis have been developed for children.

Classically, appendicitis is subdivided into (1) acute, simple appendicitis; (2) acute, complicated appendicitis; and (3) chronic appendicitis [3]. Simple appendicitis is a process that is confined to the appendix [1, 3]. Complicated, or sometimes referred to as complex, appendicitis instead indicates more advanced pathology including appendiceal perforation, phlegmonous or gangrenous changes, or an associated abscess [1, 3]. Chronic appendicitis is less common and remains a controversial topic [4]. The literature suggests this is a real entity defined by inflammation of the appendix that lasts for weeks, months, or even years [4].

## Epidemiology

The annual incidence of appendicitis is estimated at 19–28 per 10,000 children [5]. Appendicitis is more commonly diagnosed in children aged 4–14 years old [5, 6]. Children less than 4 years old have a lower annual incidence of one to six per 10,000 children per year [7]. Overall, the estimated lifetime risk of developing appendicitis is 7–8% [6, 8]. Appendicitis has a male predominance of about 55–60% [8]. The percentage of children who present with complicated appendicitis is estimated at 30%, ranging from 20% to 74% depending on the study [5, 8–11].

Higher rates of complicated appendicitis have been seen in patients with greater than 48 h' duration of symptoms, age less than 5 years old, rural geography, ethnoracial minority, public or self-insurance, obesity, and other chronic diseases [10–12]. Complicated appendicitis is also associated with increased length of stay, complications, and hospital cost [8, 11].

## Anatomy and Pathophysiology

The appendix is a blind-ending luminal structure attached to the base of the cecum near the ileocecal valve. The base of the appendix is most commonly located at McBurney's point, which is located one-third the distance from the right anterior superior iliac spine to the umbilicus. The tip of the appendix, however, can be located in various positions including pelvic, subcecal, retroileal, retrocecal, ectopic, and preileal locations. While it is most commonly positioned in the pelvis, the variations in location may affect the presenting symptoms of appendicitis and complicate the diagnosis. The appendicular

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artery, a branch of the ileocecal artery, is the blood supply of the appendix. The appendix is composed of colonic epithelium, with the submucosa containing a high concentration of lymphoid follicles, most especially in children.

Acute appendicitis is caused by obstruction of the lumen of the appendix [13]. Once obstructed, the mucosa continues to secrete mucus and fluid leading to increased pressure within the obstructed lumen [13]. The resident intestinal bacteria continue to grow and recruit neutrophils, which leads to the production of purulent fluid and even higher intraluminal pressure [13]. The high pressure causes obstruction of venous outflow and lymphatic drainage [13]. Ultimately, the arterial blood flow may also become obstructed from the significant edema, leading to transmural appendiceal ischemia [13]. Once the bacteria invade the appendiceal wall, the diseased appendix is then at high risk for perforation [13].

Most commonly caused by fecal stasis or a fecalith, obstruction of the appendix in children may also be caused by lymphoid hyperplasia from systemic infectious illness, granulomatous inflammatory changes with Crohn's disease, thick mucus seen in cystic fibrosis, parasites, or rarely appendiceal neoplasms [5, 6, 9]. Interestingly, a family history of appendicitis is associated with a nearly threefold increased risk of developing appendicitis, suggesting there may also be a genetic component [14].

## Presentation and Physical Exam

### Presenting Symptoms

Classically, appendicitis begins with the onset of gradual, constant periumbilical pain that eventually migrates and localizes to the right lower quadrant [15]. While the migration of pain is highly specific, it only occurs in approximately half of cases [15]. The periumbilical pain is due to swelling of the appendiceal lumen causing irritation of the visceral peritoneum. The right lower quadrant pain is then due to direct irritation of the parietal peritoneum and ultimately results in somatic pain.

Other common symptoms of acute appendicitis include nausea (81.7%), emesis (67.7%), and anorexia (72.4%) [16]. While most patients are afebrile or simply report a low-grade fever, high fever is uncommon and raises suspicion for perforated appendicitis [17]. In children, the diagnosis of appendicitis can be challenging because they do not always have the classic signs of right lower quadrant pain, fevers, and nausea or anorexia [8, 17]. This is especially true among younger children who may have more difficulty explaining their symptoms and may instead present with irritability, decreased activity, and refusal to eat [8, 17].

In pediatric appendicitis, approximately 50% of patients present with atypical features including normal or increased bowel sounds (64%), absence of rebound pain (52%), lack of migration of pain (50%), lack of guarding (47%), lack of anorexia (40%), and absence of maximal pain in the right lower quadrant (32%) [17]. Given many patients present with these atypical features and the classic symptoms incidentally overlap with presentations of many other common causes of childhood abdominal pain, the diagnosis of pediatric appendicitis can be quite challenging [8, 17].

### Physical Exam

On physical exam, it is important to not overlook vitals and the general appearance of the patient. Observations of tachycardia, fever, acute distress, listlessness, and irritability may all be important in establishing the diagnosis. Beyond the complete general physical exam including examination of the lungs, heart, periphery, and ear/nose/throat, the primary exam will be focused on the abdomen.

Beginning with inspection, the abdomen may or may not be distended. If the patient is old enough to participate in the exam, it can be helpful to ask the patient to point to where they feel the most pain. Next, palpate the abdomen in each quadrant, asking the patient to indicate if they experience any pain and where. Observing facial expressions during palpation can also be useful. Classically, patients will exhibit maximal tenderness at McBurney's point, though variations in the location of the appendiceal tip or complications from perforated appendicitis may result in pelvic or diffuse pain. Patients with peritonitis typically lie still and are reluctant to change positions. Gentle percussion or deep palpation with a quick release may elicit rebound tenderness and also indicate peritonitis. Less commonly, a mass may be palpated in the right lower quadrant with more advanced disease.

Classic adjunct maneuvers include the Rovsing, obturator, and psoas signs. The Rovsing sign is positive when palpation of the left lower quadrant results in right lower quadrant pain. The obturator sign is positive when pain is elicited with flexion and internal rotation of the right hip and increases suspicion for pelvic appendicitis. Finally, the psoas sign is positive when the patient is placed in left lateral decubitus position and right hip extension elicits pain; this sign increases suspicion for retrocecal appendicitis. While these physical exam maneuvers may increase the likelihood of appendicitis if positive, labs and imaging are often ordered to differentiate between appendicitis and other diagnoses with similar signs and symptoms.

## Diagnosis

### Differential Diagnosis

The differential diagnosis for pediatric conditions with overlapping signs and symptoms of appendicitis is broad and varies by sex and age. Other gastrointestinal pathologies include gastroenteritis, Meckel's diverticulitis, intussusception, inflammatory bowel disease, typhlitis, mesenteric adenitis, malignancy, bowel obstruction, and constipation. In girls, it is important to consider pelvic inflammatory disease, ectopic pregnancy, dysmenorrhea, ovarian torsion, and ovarian/paratubal cysts. Other conditions to consider include right lower lobe pneumonia, nephrolithiasis, pyelonephritis, cystitis, pancreatitis, lymphoma, Henoch-Schonlein purpura, and hemolytic-uremic syndrome.

## Diagnostics: Laboratory

There is no definitive algorithm for work-up of pediatric abdominal pain concerning for appendicitis, though some diagnostics are important to consider. First, obtaining a complete blood count (CBC) to evaluate the white blood cell count can be helpful. After the first 24 h of symptoms, the CBC may demonstrate a left shift with a predominance of neutrophils and bands [18]. While leukocytosis is a nonspecific marker of inflammation, the increase in neutrophils would increase the concern for infection [18]. It is important to note that leukopenia, rather than leukocytosis, may be present in those who are immunocompromised and may raise the concern for other conditions such as typhlitis [19]. Additionally, a urinalysis should be sent to rule out urinary tract infection and a pregnancy test sent for girls of reproductive age. If the patient reports a significant history of recent emesis and/or diarrhea, obtaining a basic metabolic panel will be helpful in evaluating for electrolyte derangements and acute kidney injury from dehydration. Children with complicated appendicitis will often present with diarrhea secondary to purulent fluid in the abdomen or pelvis causing inflammation of the intestines [20]. In those patients that report pain more in the periumbilical or right upper quadrant regions, it would also be useful to obtain liver function tests and a lipase to rule out hepatobiliary and pancreatic pathology.

## Diagnostics: Imaging

Imaging can assist with obtaining a diagnosis, reducing negative appendectomy rates and reducing lengths of stay [21]. In pediatrics, the standard imaging to begin with in diagnosing appendicitis is an abdominal ultrasound, though obtaining quality ultrasound images is user dependent [22]. The advantages of ultrasound are that it is fast, portable, and less expensive than other imaging modalities and delivers no radiation to the child. Nevertheless, visualization of the appendix may be limited by the patient's body habitus, bowel gas, abnormal location of the appendix, or severe pain that hinders abdominal compression with the ultrasound [22]. Despite these limitations, the sensitivity and specificity of diagnosing appendicitis on ultrasound is as high as 90–95% [23].

On ultrasound, an inflamed appendix in children should be greater than 6 mm in diameter and have a wall thickness greater than 3 mm [22, 24]. Other signs that may increase the suspicion for appendicitis include periappendiceal lymphadenopathy and free fluid, hyperechogenic pericecal fat, increased blood flow on Doppler scan, visualization of an appendicolith, and presence of an abscess [22, 24]. On the axial plane, an inflamed appendix will have a target appearance and will be non-compressible [22, 24]. If appendicitis is not visualized, an ultrasound can also assess for other abdominal pathologies including ovarian cysts, ovarian torsion, hepatobiliary pathology, and intussusception.

An abdominal X-ray is not specific or sensitive for diagnosing appendicitis, though may rarely demonstrate a radiopaque appendicolith. Most patients with appendicitis will have a normal-appearing abdominal X-ray [25]. An abdominal X-ray may reveal other causes of abdominal pain that mimic appendicitis, including intussusception, typhlitis, bowel obstruction, ileus, and constipation.

In cases where ultrasound is inconclusive, some hospitals elect to obtain a focused abdominal MRI (magnetic resonance imaging) [26]. Similar to ultrasound, MRI delivers no radiation to the patient, though is not user dependent and provides high-quality images with high sensitivity for appendicitis [26]. Nevertheless, if a focused MRI protocol is not in place at the institution, the scan duration may be quite long, be delayed due to other uses, or require sedation.

Many institutions, especially non-pediatric centers, use abdominal CT (computerized tomography) to diagnose any abdominal pathology. Unlike ultrasound, a CT scan is not dependent on user accuracy. CT can diagnose abdominal pathology other than appendicitis, is fast, and has high sensitivity (94%) and specificity (95%) [16]. Unfortunately, CT imaging does expose the patient to radiation and is much more expensive than ultrasound.

Given all these factors, most pediatric centers would recommend beginning with an abdominal ultrasound to evaluate for appendicitis [8, 22]. Selective use of MRI to follow an inconclusive ultrasound can be effective in establishing the diagnosis with a sensitivity of 100% and specificity of 96% [27]. These findings accompanied with a physical exam consistent with appendicitis lead to a positive predictive value of 83% and a negative predictive value approaching 100% [8, 28]. This work-up pathway has not been shown to increase the risk of perforation or negative appendectomy rates [26]. The time to treatment and length of stay are also unchanged [26].

## Scoring Systems to Evaluate for Appendicitis

Another tool that can help in determining the next step in the work-up of a patient with possible appendicitis scoring systems such as the Pediatric Appendicitis Score (PAS) (Table 49.1) [29, 30]. Based on identified signs, symptoms, and laboratory findings, the patient receives a total score from 1 to 10 [29]. The PAS score assesses for tenderness to palpation in the right lower quadrant, anorexia, low-grade fever (>38.0), nausea/emesis, leukocytosis (>10,000/mm$^3$), left shift (>75% neutrophils), migration of pain to the right lower quadrant, and cough/percussion/heel tapping tenderness in the right lower quadrant. Studies have demonstrated that using the score alone is not sufficient to diagnose appendicitis, but using it in tandem with imaging can risk stratify patients for suspected appendicitis, decrease the time to diagnosis, and limit radiation exposure [8, 29, 30]. In fact, false-negative ultrasound findings decrease with increasing PAS, and conversely false-positive ultrasound findings increase with decrease PAS [30]. There are other validated, risk stratification scoring systems such as the Alvarado score [31] and the Appendicitis Inflammatory Response (AIR) score [32]. All three systems have utility, and differences in the various components of the scoring systems illustrate the challenges in making a confident diagnosis of appendicitis in the emergency setting. None of these systems takes into account two other key factors such as the duration of symptoms or whether the pain is constant or intermittent in nature. We propose that a new scoring system incorporating these factors might have improved diagnostic yield.

**Table 49.1** Comparison of the Pediatric Appendicitis Score (PAS), Alvarado score, and the Appendicitis Inflammatory Response (AIR) score. All three are validated, risk stratification scoring systems, in common use by emergency medicine physicians. The Pediatric Appendicitis Score appears to be the most used system

| | | **Scoring system** | | |
|---|---|---|---|---|
| | | **PAS** | **Alvarado** | **AIR** |
| ***Symptoms*** | | | | |
| | Nausea or vomiting | 1 | 1 | – |
| | Vomiting | – | – | 1 |
| | Anorexia | 1 | 1 | – |
| | Migration of pain to RLQ | 2 | 1 | – |
| ***Signs*** | | | | |
| | Pain in RLQ | 2 | 2 | 1 |
| | Rebound tenderness | 1 | 1 | – |
| | Light | – | – | 1 |
| | Medium | – | – | 2 |
| | Strong | – | – | 3 |
| | Body temperature >37.5 °C | – | 1 | – |
| | Body temperature >38.5 °C | 1 | – | 1 |
| ***Laboratory tests*** | | | | |
| | Leukocytosis shift | – | 1 | – |
| | PMN leukocytes (>75%) | 1 | – | – |
| | 70%–84% | – | – | 1 |
| | >85% | – | – | 2 |
| | *WBC* | | | |
| | >10 × 109/L | 1 | 2 | – |
| | 10.0–14.9 × 109/L | – | – | 1 |
| | >15.0 × 109/L | – | – | 2 |
| | *CRP Concentration* | | | |
| | 10–49 g/L | – | – | 1 |
| | >50 g/L | – | – | 2 |
| ***Total score*** | | 10 | 10 | 12 |
| **Risk of appendicitis** | | **PAS score** | **Alvarado score** | **AIR score** |
| | *Low-risk* | 1–4 | 1–4 | 0–4 |
| | *Intermediate-risk* | 5–7 | 5–6 | 5–8 |
| | *High-risk* | 8–10 | 7–10 | 9–10 |

*Abbreviation*: *RLQ* Right lower quadrant

In instances where the diagnosis remains unclear, patients can be admitted for observation and serial abdominal exams. In cases of diagnostic uncertainty, antibiotics are generally withheld as antibiotics may effectively teat early appendicitis and mask developing symptoms. Most patients' symptoms will either resolve or progress, and the diagnosis should become clear.

## When to Consult Surgery or Transfer the Patient to a Center with Pediatric Surgery

Whenever there is a concern for an acute abdomen, surgery should be consulted sooner rather than later. However, if the patient is clinically stable, there is time to begin the diagnostic work-up prior to consultation. Using the PAS tool can be useful to risk-stratify patients and to determine when to consult surgery [29, 30].

For patients with a PAS >6, surgical consultation is warranted, and a discussion with the surgeon regarding whether abdominal imaging is indicated [29, 30]. For patients with a PAS 4–6, it is often helpful to obtain cross-sectional imaging such as an ultrasound or MRI [29, 30]. If the appendix is not visualized on the imaging, then surgical consultation may be reasonable to decide on the disposition of the patient. If the PAS is <4, the patient has a low likelihood of appendicitis and does not necessarily warrant further imaging [29, 30]. This patient is less likely to benefit from a surgical consultation, and other causes of acute abdominal pain should then be considered.

If the patient is being seen in a hospital without pediatric surgery, the provider should consider transferring the patient after establishing the diagnosis or when there is any concern for a possible need for surgical intervention [33, 34].

## Management

### Initial Management of All Appendicitis Patients

Once the diagnosis of appendicitis is established, the most important first step in management is resuscitation and initiation of antibiotics [6, 8]. Fluid resuscitation may begin prior to completing the work-up, as most patients with appendicitis are dehydrated [6, 8]. The choice of antibiotics varies across institutions. Antibiotics should cover enteric flora including gram-negative and anaerobic bacteria. Providers should also consider the patient's allergy history and their hospital's local antibiogram and resistance patterns.

### Surgical Management: Appendectomy

The gold standard treatment for appendicitis is appendectomy, either open or laparoscopic [1, 35]. Both approaches have good outcomes, though patients who undergo laparoscopic appendectomy report less pain, faster discharge, earlier mobilization, and early resolution of ileus [1, 35]. Additionally, laparoscopic appendectomies allow for a better cosmetic result and the ability to easily assess for other intraabdominal pathologies [1, 35]. If the appendix appears normal and no other pathology is identified, most surgeons will still remove the appendix to reduce the diagnostic conundrum if the symptoms persist or return. There are very few contraindications to appendectomy, though patients presenting in septic shock should be resuscitated prior to undergoing surgery. The appendectomy should be performed with some degree of urgency (<24 h from presentation), though does not to be performed emergently (<2 h from presentation) [36].

Several studies support a shift away from the traditional thinking that appendicitis was an emergency and that surgery ought to be performed immediately at the time of diagnosis [37–39]. Children presenting with >48 h of symptoms are more likely to present with complicated appendicitis; however the length of time from diagnosis to the operating room appears to play little to no role in whether the appendix will "perforate" while they await the operating room [37–39]. A study of 230 children which examined the impact of the time from diagnosis to appendectomy supports this change in thinking [38]. Children taken to the operating room at 0–3 h, 4–6 h, or longer than 6 h after diagnosis of appendicitis were not found to have a statistically significant difference in perforation rates or hospital length of stay [39]. Appendectomies that are performed emergently are not associated with decreased rates of perforation or other complications relative to those performed up to 24 h after presentation [37, 38]. Additionally, there is evidence to suggest those children rushed to the operating room may have a higher rate of post-operative surgical site infection in non-perforated patients and that children operated on after overnight fluid resuscitation and antibiotics have a lower risk of post-operative abscess [35, 40]. While in-hospital surgical delay does not appear to increase the risk of finding complicated appendicitis at the time of surgery, delays in patient presentation to the hospital are associated with a 4.9 times increased odds of perforation and a 56% increase on hospital length of stay [40].

After appendectomy, it is important to send the appendix specimen to pathology for review. The diagnosis should be confirmed with histology that may demonstrate acute inflammatory infiltrate, necrosis, thrombosis, and possible transmural infarction in perforated appendicitis. Other pathologies, besides appendicitis, may also be seen. Occasionally, no pathology at all is visualized. The rate of negative appendectomies for pediatric patients is estimated at 3.6%, though is higher for children less than 5 years old and girls older than 10 years old [41]. Patients who undergo diagnostic imaging pre-operatively have lower rates of negative appendectomies, regardless of age or sex [21]. Balancing the risks of perforated appendicitis, a negative appendectomy rate of less than 5% is acceptable at most institutions.

Children with simple appendicitis can be discharged soon after surgery once they demonstrate adequate pain control and oral intake [42]. They do not require further antibiotics. Patients with complicated appendicitis are admitted and maintained on intravenous antibiotics. The total antibiotic duration, intravenous and oral, should be approximately 3–7 days, though varies by patient and provider [43]. Some patients experience post-operative ileus, so their diets are advanced more slowly and occasionally require nasogastric decompression [1]. In patients who are not receiving oral nutrition after 1 week, parenteral nutrition should be considered. Patients with complicated appendicitis are also at high risk for a post-operative inflammatory response and are likely to require ongoing resuscitation with close attention paid to their urine output [1, 6, 8]. Finally, complicated appendicitis significantly increases the risk of development of a post-operative intraabdominal abscess or wound infection [8, 44]. Fever on post-operative day 5 or later should include examination of the incisions and consideration of imaging to rule out a possible intra-abdominal infection. Most patients with complicated appendicitis will have resolution of their symptoms by post-operative day 5. In cases where there is concern for an abscess, waiting until post-operative day 7 before scanning a patient will lead to fewer drainage procedures and decrease the need for additional cross-sectional imaging [45]. Depending on the size and location, well-formed fluid collections can be managed by antibiotics, image-guided drainage, or operative drainage [45].

## Nonoperative Management

Patients who present with large well-formed abscesses from perforated appendicitis may benefit from delay in appendectomy [46]. These patients have often had symptoms for several days prior to presentation. Management consists of resuscitation, intravenous antibiotics, and bowel rest (NPO). The abscess is then drained percutaneously if safely accessible and a drain left in place to allow for ongoing drainage [46]. Patients' diets are slowly advanced, and the patient is discharged home on antibiotics with or without the drain in place.

Recently, many researchers have demonstrated resolution of pediatric appendicitis with antibiotics alone [47]. Patients are admitted for observation, intravenous antibiotics, resuscitation, and bowel rest. As their pain improves, patients' diets can be slowly advanced. Once their pain is resolved, they are no longer having fevers, and they are tolerating a regular diet, patients can be discharged home to complete an oral course of antibiotics. However, if patients demonstrate new-onset hemodynamic instability, rising leukocytosis, worsening pain, or persistent fevers after 24 h, the conservative nonoperative management is deemed unsuccessful, and appendectomy should be reconsidered [48]. For patients with perforated appendicitis, conservative management fails in as many as 10–25% of children [48]. Additionally, patients with evidence of an appendicolith are at high risk for failure of conservative management at 72% [49]. In patients with simple appendicitis, conservative management is successful in 72.7–90% of cases in resolving symptoms [50–52]. Conservative management is associated with longer lengths of stay, repeat imaging, and prolonged antibiotics [47].

Interval appendectomy can be offered after conservative management of appendicitis. Interval appendectomies are typically performed 2–3 months after the initial bout of appendicitis. Some proponents of conservative management are beginning to question whether interval appendectomy is necessary [53]. Interval appendectomies decrease the chance of recurrent appendicitis and allow for the evaluation of alternative pathology, such as inflammatory bowel disease or a neoplasm that led to the appendicitis. However, others report the risk of recurrent appendicitis is low enough to avoid subjecting the patient to the anesthesia, surgical risk, and extra cost [53]. As the utility of interval appendectomies and conservative management of appendicitis continue to be debated, patient and family preference will be useful in determining treatment plans. Ultimately, it is important to practice shared decision-making and to recognize patient reported outcomes such as pain, quality of life, disability, general anesthesia avoidance, and acceptance of the risk of recurrent appendicitis [54].

## Follow-Up and Post-Operative Complications

After discharge, patients may develop a wound infection (<2% for laparoscopic appendectomy and 3–11% for open appendectomy) or an intraabdominal abscess (5% for simple appendicitis and 15% for complicated appendicitis) [8, 55, 56]. Evidence of cellulitis around the incision sites, fever, or ongoing abdominal pain requires further evaluation and possible diagnostic studies.

While waiting for an interval appendectomy after conservative treatment, approximately 10% of patients will have recurrent appendicitis. For those who do not undergo interval appendectomy, the risk of recurrent appendicitis ranges from 5% to 37% within the first year from the initial appendicitis diagnosis [53, 57]. After that year, the risk returns back to the general population lifetime risk of 7% [1]. However, patients with evidence of appendicolith are at increased risk or recurrence and therefore should undergo interval appendectomy [58].

The majority of patients do very well with timely management of appendicitis. Overall, the mortality rate for pediatric appendicitis is 0.1–1% and most commonly occurs in neonates and infants, where appendicitis is less common and diagnosed later [5, 55].

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