

Introduction/Preface

This document is intended to provide guidance for management of pediatric appendicitis to remote providers in locations that have variable access to subspecialty care and imaging technologies. In order to do this, we have provided evidence-based guidance wherever possible and when this is lacking, expert opinion. There are multiple embedded links to randomized studies, review articles and consensus statements. This document is not intended to be completely comprehensive or reflective of the entire body of knowledge on the subject. However, the content reflects what the group felt was most relevant for the target audience. While we attempted to draw on open access content to the greatest degree possible, some of the links will be limited in availability with out the appropriate institutional or individual subscriptions. APSA would greatly appreciate your feedback on the relevance and effectiveness of this educational product.

Sincerely,

The APSA Rural Surgery Educational Subcommittee

Pediatric Appendicitis Handbook for Rural/Remote Providers

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Diagnostic Considerations

Clinical Assessment

Clinical Scoring Systems

Bottom Line: In general, scoring systems based on history, exams, and laboratory tests are useful for excluding the diagnosis of appendicitis. However, relying on scoring systems alone to make the diagnosis is not recommended.

The clinical diagnosis of appendicitis in children is challenging. Common alternate causes of abdominal pain include constipation, mesenteric adenitis, and pneumonia. Less common etiologies are infectious enteritis or colitis, omental infarct, urolithiasis, Meckel's diverticulitis, and inflammatory bowel disease.

- In girls, consider ovarian torsion; in adolescent girls, consider ovarian cysts and pelvic inflammatory disease.
- If there is a recent history of a positive COVID-19 test, also consider multisystem inflammatory syndrome in children due to COVID (MIS-C).

Pediatric Appendicitis Score (PAS)

The pediatric appendicitis score is a commonly utilized clinical tool to determine the need for imaging and surgical evaluation.

Use in children 3–18 years old who present with right lower quadrant (RLQ) abdominal pain and are suspicious for possible appendicitis to stratify patients into low risk, equivocal, and high risk categories.

- Score < 4: Unlikely to be appendicitis
- Score 4–6: Equivocal, consider imaging if possible
- Score > 6: Likely appendicitis

Variable	Score
Anorexia	1
Nausea/Vomiting	1
Fever	1
Migration of pain	1
Cough/percussion/hop tenderness	2
Right lower quadrant tenderness	2
Leukocytosis	1
Neutrophilia	1
Max total score	10

Leukocytosis (WBC > 10,000)
Neutrophilia (ANC > 7,500)

[Pediatric Appendicitis Score](#)

Common Conditions that can Mimic Appendicitis

Gastroenteritis

- Patients typically present with generalized cramping, abdominal pain, diarrhea, vomiting, and anorexia.
- Patients may report sick contact or contaminated food prior to developing symptoms.
- The pain is typically poorly localized but can be centered in the RLQ.
- There is often associated diarrhea or vomiting, sometimes prior to the onset of pain.
- Leukocytosis can be seen, but other inflammatory markers are usually not elevated.
- Ultrasound (US) may fail to see the appendix, but the study will often note enlarged mesenteric nodes.

Constipation

- The pain may be localized in the right or left side of the abdomen and can be severe but often intermittent.
- A clear history of constipation may not always be present. Inflammatory markers are not typically elevated.
- Peritonitis is usually not seen on physical exam.
- A plain x-ray of the abdomen may be very useful in making the diagnosis.
- The appendix may be enlarged but is not inflamed on ultrasound or CT.

Ovarian Torsion/Pelvic Inflammatory Disease

- Can be very difficult to distinguish clinically from appendicitis.
- Should be considered in all post-pubertal girls; ovarian masses can also be seen prior to puberty.
- Imaging with ultrasound is essential to distinguish this from appendicitis.

MIS-C

- Can be seen even following asymptomatic COVID-19 infection (typically within 8 weeks).
- Abdominal pain is a common complaint; however, fevers and inflammatory markers are usually elevated out of proportion to pain and tenderness.
- Elevated troponin/atrial natriuretic peptide seen frequently with MIS-C in the presence of COVID-19 antibodies can distinguish this from appendicitis.
- The presence of COVID-19 antibodies is essential to making a diagnosis.

Henoch-Schonlein Purpura

- Crampy pain occurs in the presence of a purpuric rash.

Pneumonia

- Can present with abdominal pain and sometimes tenderness.
- A chest x-ray should be considered if the patient is febrile, and the physical exam and abdominal imaging are inconclusive.

Useful Physical Exam Maneuvers in Young Children

- Talk to the child and their parent/guardian during the exam to help relax the patient.

- If possible, examine the patient in the presence of their parent/guardian/family member.
- Utilize distraction techniques for the abdominal exam, including using your stethoscope to palpate while auscultating and asking non-medical questions (school, hobbies, etc.).
- Take into account activity: Unwillingness to move around the bed and jumping up and down suggest peritonitis.
- Children in pain but moving/writhing around the bed, or screaming and running away typically do not have peritonitis.

[How to Perform a Pediatric Abdominal Exam](#)

Laboratory Evaluation

Elevated white blood cell (WBC) counts and proportion of PMN cells are typically utilized in evaluating pediatric abdominal pain. While these tests can be sensitive, they are not particularly specific.

The same is true for C-reactive protein (CRP), which is sensitive when elevated but lacks specificity.

As with clinical scoring systems, these studies can be useful to exclude appendicitis; however, in early cases of appendicitis, the WBC count can be normal. Their utility in making the diagnosis is limited in the absence of compelling clinical or imaging findings.

In patients with equivocal clinical presentations and imaging findings admitted for observation, trending the WBC and CRP can be very useful. If these markers trend down without antibiotics or surgery, this argues against a diagnosis of acute appendicitis.

<https://westjem.com/diagnostic-acumen/diagnosing-appendicitis-evidence-based-review-of-the-diagnostic-approach-in-2014.html>

Utilization of urinalysis, B-HCG, amylase, and liver enzymes can be useful to exclude other diagnoses—similar to adults.

Imaging

Most institutional protocols at children’s hospitals utilize ultrasound as the first-line imaging modality for abdominal pain in children and reserve cross-sectional imaging for cases where ultrasound is non-diagnostic and the clinical suspicion of appendicitis is high.

In cases where ultrasound is non-diagnostic and the clinical suspicion is low or moderate, consideration could also be given to admission for clinical observation, with or without trending of inflammatory markers. Shared decision making with parents or guardians may also be appropriate when deciding on admission or advanced imaging with CT scan.

Signs of Appendicitis on Imaging and Optimal Imaging Techniques

Ultrasound

Ultrasound is the most cost-effective and safest first-line imaging modality for all pediatric patients with suspected appendicitis.

Positive ultrasound The appendix is visualized and the findings (dilated/non-compressible appendix, peri-appendiceal fluid, appendicolith) suggest appendicitis.

Negative ultrasound The appendix is completely visualized (including the tip and junction with the cecum) and appears normal, without secondary signs* of appendicitis. If the appendix is completely visualized, the sensitivity and specificity for pediatric appendicitis are excellent: 98.8% and 98.3%, respectively.

Equivocal ultrasound The appendix is not visualized, incompletely visualized, or the findings are indeterminate, including secondary signs* of appendicitis.

***Secondary signs** Free fluid, fluid collections, echogenic fat, hyperemia of the appendix, abnormal mesenteric lymph nodes, abnormal adjacent bowel, bowel wall edema, and appendicoliths.

An equivocal ultrasound that fails to visualize the appendix may still be useful, as the most common reason the appendix is not seen is because it is normal. In patients with a low clinical suspicion of appendicitis, an equivocal ultrasound can support this suspicion, particularly if the laboratory data (WBC and CRP) are normal. If clinical suspicion is high and the ultrasound is equivocal, consider cross-sectional imaging.

[Secondary Signs May Improve the Diagnostic Accuracy of Equivocal Ultrasounds for Suspected Appendicitis in Children](#)

[US for Suspected Appendicitis in Children](#) (Video)

CT Scan

Computerized tomography (CT) scans are readily available, fast, and highly accurate. However, due to concerns about radiation exposure and the subsequent potential to increase malignancy later in life, they are typically not the first-line study for pediatric abdominal pain.

- Negative predictive value (NPV) of a normal CT examination in pediatric patients: 99.8% if the appendix is visualized and 98.7% if the appendix is not visualized.
- IV contrast is recommended to provide the best images. Oral contrast is not universally required but may occasionally be helpful, particularly in small children.
- Signs on CT of appendicitis are like those seen in adults, but recognition of peri-appendiceal stranding may be limited due to a lack of intra-abdominal fat.
- An increased appendiceal diameter and wall thickening are primary signs of appendicitis. Lack of filling with oral contrast or lack of air in the appendix are other signs suggestive of appendicitis.
- Although the carcinogenic effect of radiation exposure from CT remains controversial, numerous epidemiologic studies have demonstrated an association with a mild increase in malignancy later in life. A recent study found that CT-exposed patients who underwent appendectomy had an elevated risk of developing leukemia

later in life (IRR 1.40 [98.75% CI, 1.04–1.87]). CT is therefore not recommended as the initial imaging modality for abdominal pain in children but should be strongly considered in the face of moderate to high clinical suspicion and a non-diagnostic ultrasound.

- In facilities where ultrasound is not available and clinical suspicion is high, CT should be considered. If clinical suspicion is equivocal, then admission for clinical observation and trending of inflammatory markers should be considered.

[Suspected Appendicitis in Children: Diagnostic Importance of Normal Abdominopelvic CT Findings with Non-visualized Appendix](#)

[Risk of Hematologic Malignant Neoplasms From Abdominopelvic Computed Tomographic Radiation in Patients Who Underwent Appendectomy](#)

[Pediatric Computed Tomography and Associated Radiation Exposure and Estimated Cancer Risk](#)

MRI

Magnetic resonance imaging (MRI) carries a comparable sensitivity/sensitivity rate to a CT scan. However, it is costly, not readily available in many institutions, and may also require sedation.

- Rapid protocols can be completed in 15 minutes.
- These are generally limited to axial and coronal T2-weighted fast spin-echo sequences with and without fat saturation.
- MRI results in a similar benefit in terms of reduced rates of equivocal assessments for pediatric appendicitis, but its utility is limited by availability, cost, and the potential need for sedation. Like CT, it is very accurate and useful as a second-line imaging study for an equivocal ultrasound.

[Emergency Abdominal MRI Protocols](#)

Putting It All Together

	Benefits	Risks/Limitations
Ultrasound	<ul style="list-style-type: none"> - low cost - widely available - avoids sedation, contrast agents, and radiation exposure - high sensitivity/specificity if appendix clearly visualized 	<ul style="list-style-type: none"> - operator-dependent - patient factors (pain, bowel gas, body habitus) can limit exam - high rate of equivocal studies (up to 60%)
Computerized Tomography	<ul style="list-style-type: none"> - fast - readily available - less operator-dependent than ultrasound - highly accurate: sensitivity/specificity 95% 	<ul style="list-style-type: none"> - ionizing radiation exposure - requires intravenous (IV) contrast - may require sedation in younger children
MRI	<ul style="list-style-type: none"> - avoids ionizing radiation - not impacted by operator/patient factors - sensitivity/specificity 90–96% 	<ul style="list-style-type: none"> - availability limited at many institutions - may require sedation or be limited by significant motion artifacts - increased costs

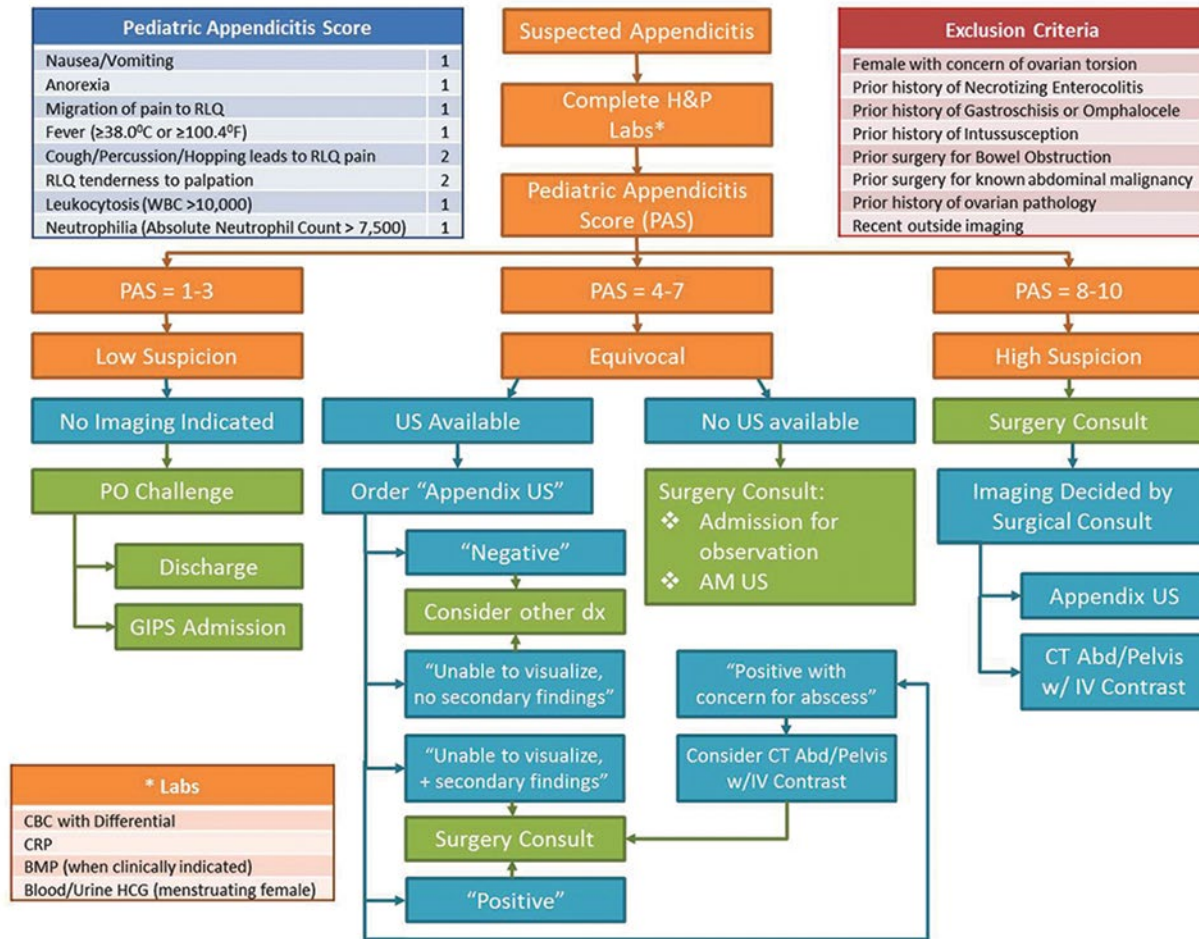
When developing a local imaging algorithm for the evaluation of pediatric appendicitis, each institution should consider local resources and the surrounding support network. Items to consider should include the following:

- Availability of ultrasound technicians (during normal business hours and after hours)
- Historical institutional accuracy with pediatric ultrasounds
- Availability of CT scan using ALARA guidelines
- Availability, cost, and time expenditure of MRI
- Pediatric (or adult) general surgeon availability for consultation
- Comfort level of local providers with clinical assessment of the child
- Feasibility of transport to an institution with more resources
- Clinical stability of the child

[American College of Radiology Appropriateness Criteria® Right Lower Quadrant Pain—Suspected Appendicitis](#)

[Practical Imaging Strategies for Acute Appendicitis in Children](#)

Next is an example of an algorithm to risk stratify patients based on the clinical degree of suspicion for pediatric appendicitis. Although local protocols will vary based on available resources, this provides a good framework. As stated above, the threshold for cross-sectional imaging at each institution depends on local resources.



Clinical decision algorithm based on the Pediatric Appendicitis Score (PAS), from Children's of Alabama, Birmingham. GIPS: General Inpatient Pediatric Service
https://www.childrensal.org/workfiles/Clinical_Services/general_surgery/Algorithm-to-Help-Diagnose-Appendicitis.pdf

Treatment Considerations

Uncomplicated (Nonperforated) Appendicitis

Bottom Line: Surgical treatment has long been the preferred management for simple appendicitis. Medical management (antibiotics alone) has emerged as a safe alternative for most children. However, while most cases managed medically do well, concerns exist regarding significant 1- and 5-year failure rates (10–20% and 25–50%, respectively), more emergency room visits, higher rates of imaging studies, and potentially a higher rate of perforation should the disease recur. Ongoing randomized trials are underway; however, most agree that this is an option that warrants discussion with most families regarding potential risks and benefits.

[Nonoperative Management of Uncomplicated Appendicitis](#)

Medical Management for Uncomplicated Appendicitis

Risks

- **Potentially longer hospitalization:** Most protocols for medical treatment call for admission with broad-spectrum antibiotics (ceftriaxone/metronidazole or piperacillin/tazobactam) until symptoms improve, then discharge home on an oral regimen to complete a 7–10 day course.
- **Early failure:** Worsening abdominal pain or non-resolution of symptoms of appendicitis within first 12–24 hours on IV antibiotics (early failure). Quoted rates of 5–15% largely depend on threshold of time to abandon medical therapy. Delaying surgery does not result in an increased perforation rate in the short term or make the procedure more difficult; however, it will likely prolong hospitalization.

Who should NOT be considered for medical management?

- **Appendicoliths:** Patients with appendicoliths on imaging are at higher risk for both early and late treatment failures. In general, the presence of an appendicolith is considered a contraindication to non-operative treatment.

See above: [Nonoperative Management of Uncomplicated Appendicitis](#)

[High Failure Rate of Nonoperative Management of Acute Appendicitis with an Appendicolith in Children](#)

Recurrence of Appendicitis/Failure of Medical Management

Approximately 10% in the first year. However, 50% of children treated nonoperatively in one prospective study had their appendix removed within 5 years. Pathologic examination of these specimens demonstrated that a relatively low proportion had appendicitis (10%). This suggests that patient anxiety regarding recurrence contributes significantly to the desire for subsequent appendectomy. In addition, patients managed nonoperatively tend to have more visits to the emergency room and imaging studies following nonoperative management, also likely due to anxiety surrounding the risk of recurrence. One retrospective study also demonstrated a higher

perforation risk if the disease did recur. A prospective multicenter study showed no difference with strict established criteria for inclusion in non-operative management.

Benefits

- Potentially lower hospital costs in the short term but not the long term.
- Avoidance of immediate surgery in patients opposed to it.

[Effectiveness of Patient Choice in Nonoperative vs Surgical Management of Pediatric Uncomplicated Acute Appendicitis](#)

[Association of Nonoperative Management Using Antibiotic Therapy vs Laparoscopic Appendectomy With Treatment Success and Disability Days in Children With Uncomplicated Appendicitis](#)

[Five-Year Follow-up of Antibiotic Therapy for Uncomplicated Acute Appendicitis in the APPAC Randomized Clinical Trial](#)

Surgical Treatment of Uncomplicated Appendicitis

Risks

- Relatively low. Most quote a complication rate of 5% or less.

Benefits

- Can typically be done as an outpatient, with discharge from recovery room in many cases.
- Higher short-and long-term success rates than medical treatment.

Optimal Timing of Surgery

Delaying surgical intervention for up to 24 hours is considered safe if antibiotics are given promptly at the time of diagnosis.

[Time to Appendectomy and Risk of Complicated Appendicitis and Adverse Outcomes in Children](#)

Technical Considerations for Surgery

A common problem encountered in operating on smaller patients with adult instruments is lack of working space and the ability to accommodate larger instruments while maintaining good visualization.

If a standard 3-port appendectomy is used, the mesentery can be controlled with cautery or a stapler. If a stapler is utilized, the smallest possible load on the mesentery should be considered (gray) to minimize bleeding risk.

Ligature of the appendix can be done with a stapler, endo-loop device, or even XL hem-o-lock clips.

Intra-abdominally, note where working space can be obtained. Trocars should be withdrawn as far out of the abdominal wall as possible while maintaining purchase of the soft tissue on the sleeve. Mobilization of the cecum further into the pelvis or up into the right upper quadrant can allow for more working space than along the pelvic sidewall. Physiologic attachments of the cecum to the right lower quadrant can be lysed with blunt or sharp dissection. If using a stapler, complete insertion of the stapler through a 12 mm trocar into this free space (again, usually right upper quadrant or pelvis) can facilitate the full operating range of the stapler jaws. Occasionally, the trocar may need to be withdrawn over the shaft of the stapler to be able to operate the jaws. Pneumoperitoneum can usually be maintained with an increase in insufflation flow.

Another option is to mobilize the appendix and then remove it extracorporeally:

- If the appendix can be mobilized and exteriorized through the umbilical port, the mesentery can be controlled with handheld cautery and the stump suture ligated. This can be done with an optical scope with a working channel:

[Transumbilical Laparoscopic-assisted Appendectomy in Children: Clinical and Surgical Outcomes](#)

- Or with a multichannel glove port, if available:

[Transumbilical Laparoscopic-assisted Appendectomy is a Useful Surgical Option for Pediatric Uncomplicated Appendicitis: a Comparison with Conventional 3-port Laparoscopic Appendectomy](#)

- Alternately, several trocars can be placed through the same umbilical incision or one trocar for the scope and a grasper next to it without the scope:

[Transumbilical Laparoscopic Assisted Appendectomy](#) (Video)

- Another option is to place a 5 mm laparoscope through the umbilicus and a 10 mm working port placed in the RLQ from which the appendix is grasped and extracted.

In all these approaches, the appendix is visualized, adhesions are taken down bluntly, and then it is exteriorized and removed. These techniques can be difficult in cases where the appendix is very retrocecal.

Open Appendectomy

Understand the technique for open appendectomy in pediatric patients over 5 years in resource-limited settings.

Muscle-sparing incision over McBurney's point

A small (2–4 cm) incision in McBurney's point is adequate in most small children, and the appendix can be mobilized into the wound with a finger then grasped. Suction should be passed deep into the pelvis anterior to the rectum, above the liver, and along the right paracolic gutter to drain any unseen purulent fluid, as these areas are not visualized well.

[Open Appendectomy Technique: Surgical Removal of Appendix, Postoperative Care, Complications](#)

Postoperative Care

Pain management

- Provision of narcotics postoperatively has no clear benefit and may contribute to nausea and constipation.
- Most children can be managed on scheduled acetaminophen with the addition of ibuprofen or ketorolac.
- Confirm with the parents whether the child can take medications in liquid or pill form.
- Weight-based dosage can be confusing for both the family and the provider: manufacturers' charts can be helpful ([see Dosing on Call](#)). Acetaminophen is typically dosed every 6 hours, and ibuprofen is typically dosed every six to eight hours. When paired, it is sometimes practical to alternate medications every 3 hours.

Antibiotics

While preoperative antibiotics are indicated, additional postoperative antibiotics are not recommended.

Discharge Criteria

Children with nonperforated appendicitis can typically be discharged home from the recovery room. Patients who require IV medications for pain or IV fluids for nausea may justify admission.

Perforated/Complicated Appendicitis

Bottom Line: While appendectomy for perforated appendicitis is considered a routine procedure by most general surgeons, perforated appendicitis continues to be a significant source of morbidity and, rarely, mortality in children. Risk factors for perforation include duration of illness greater than 3 days, young age, hyponatremia, and bacteremia on presentation. Children who present with diffuse peritonitis on exam or who have significant intra-abdominal contamination found intraoperatively are at risk for prolonged hospitalization and surgical complications. **Providers in austere locations without robust inpatient pediatric nursing and critical care support caring for these children should consider early discussions with a referral center regarding treatment options and thresholds for transfer.** Medical treatment alone is an option for a carefully selected subset of children with perforated appendicitis.

[Perforation Risk in Pediatric Appendicitis: Assessment and Management](#)

Medical Management of Perforated/Complicated Appendicitis

Candidates

Medical treatment is considered a reasonable and potentially preferable option in well-appearing, minimally symptomatic children with prolonged duration of symptoms and a mature phlegmon

with or without an abscess on imaging. Percutaneous drainage should be considered in the presence of a well-defined abscess > 3–5 cm.

Children who have abscess/phlegmon due to complex appendicitis and an appendicolith may be treated with nonoperative management and interval appendectomy but have a higher likelihood of failing nonoperative management and of recurrent disease.

[Diagnosis and Treatment of Acute Appendicitis: 2020 Update of the WSES Jerusalem Guidelines](#)

Duration of Antibiotics

This is controversial; however, most agree that broad-spectrum antibiotics (piperacillin/tazobactam or ceftriaxone and metronidazole) should be given for at least 48–72 hours. Some protocols call for the total duration to be based on clinical factors. When patients are tolerating per os (PO) well, transition to oral antibiotics can be considered after 48–72 hours for a total 7–10-day course.

[Diagnosis and Treatment of Acute Appendicitis: 2020 Update of the WSES Jerusalem Guidelines](#)

Role of Interval Appendectomy

The role of interval appendectomy following successful medical management is controversial. Prior studies have demonstrated that medical treatment of perforated appendicitis is associated with a longer time to return to full activity. However, these studies all included interval appendectomies in that analysis.

The risk of recurrent appendicitis following perforation is commonly quoted at 7–13%. However, following perforation the risk of interval appendectomy may be similar. In completely asymptomatic patients, forgoing interval appendectomy may be reasonable if they understand the risk of recurrence. In patients who continue to have symptoms following treatment, or who have recurrent disease, interval appendectomy should be considered.

[Diagnosis and Treatment of Acute Appendicitis: 2020 Update of the WSES Jerusalem Guidelines](#)

Surgical Treatment of Perforated/Complicated Appendicitis

Surgical treatment is generally considered preferable for source control in ill-appearing patients with peritonitis. This should be done following administration of IV antibiotics and appropriate preoperative resuscitation.

Recovery from surgical appendectomy for perforation with extensive peritonitis has a significant risk of complications, with abscess rates of 10–20% and the potential for prolonged ileus and obstruction. In an austere location, if inpatient pediatric nursing support is insufficient, then consideration should be given for transfer to a higher level of care.

[Diagnosis and Treatment of Acute Appendicitis: 2020 Update of the WSES Jerusalem Guidelines](#)

Intraoperative Surgical Management of Perforated/Complicated Appendicitis(CA)

See the discussion above on surgical approaches for uncomplicated appendicitis. The techniques are similar, and all approaches can be utilized in the event of perforation.

Both open and laparoscopic appendectomies can safely be performed on CA. However, for providers not comfortable with laparoscopy in small children or in austere conditions, the open approach should be considered in patients with severe peritonitis and significant ileus/intestinal dilation.

Considerations

- Ligate or staple the appendix as close to the cecum as possible to prevent recurrence with stump appendicitis.
- Aspirate purulent material. There is no benefit to high-volume lavage of the peritoneal cavity.
- Drains are not generally supported unless there are large abscess cavities with significant residual contamination, or if removal of the appendix is not feasible due to severe inflammation.
- If inflammation in the pelvis is too severe to allow for safe appendectomy, drains should be placed, abscesses aspirated, and the procedure terminated.
- If an appendicolith was present on imaging and the appendix is grossly perforated, search for the appendicolith in the peri-appendiceal area or pelvis.
- In the case of perforation, it is important to carefully inspect the abdomen and pelvis and suction out any pus/feculent material to the greatest degree possible.

[Diagnosis and Treatment of Acute Appendicitis: 2020 Update of the WSES Jerusalem Guidelines](#)

Postoperative Care

Pain Management

For patients with significant ileus postoperatively, pain can usually be managed with scheduled intravenous acetaminophen and ketorolac. Ketorolac dosing is 0.5 mg/kg up to 30 mg and should be discontinued after a maximum duration of 5 days. Narcotics can be given for breakthrough pain in morphine-equivalent doses of 0.05 mg/kg to 0.1 mg/kg every 2–3 hours.

Fluid Management

Maintenance fluids are given according to the 4:2:1 rule. An hourly rate is calculated as 4 mL/kg for the first 10 kg, another 2 mL/kg for the second 10 kg, and another 1 mL/kg for any kilo over 20 kg (i.e., a 22 kg patient receives 62 mL/h).

In general, pediatric surgical patients should not be given hypotonic intravenous fluids postoperatively and will also require dextrose to prevent hypoglycemia.

Fluids such as D5LR or D5NS with 20 mEq/L of KCL can be given at a maintenance to a maintenance and a half rate. This should be titrated to adequate urine output. In smaller children, intravenous (or oral) boluses of potassium or magnesium can be dangerous. Therefore, it is preferable to replace ongoing losses instead of catching up on deficits.

Children with nasogastric (NG) tubes in place that drain more than 1 mL/kg every 8 hours should have their losses replaced with intravenous 1/2NS with 20 mEq/L of KCL. Children can tolerate mild hypokalemia well and in general do not need boluses with potassium until they reach levels below 2.5 mEq/dL.

Due to the pain and difficulty of blood draws, electrolytes are not typically monitored as frequently as in the adult population.

[Maintenance Intravenous Fluids in Children](#)

Nutritional Support

As with adults, previously healthy children outside of the newborn period or early infancy can go about 7 days without nutritional support if fluid, glucose, and electrolyte requirements are provided. In cases where an ileus is more prolonged than this, parenteral nutrition should be considered. In remote or austere locations, transfer to a higher level of care should be considered.

Antibiotics

Optimal strategies are controversial, but broad-spectrum antibiotics (piperacillin/tazobactam or ceftriaxone and metronidazole) should be given for at least 72 hours. Many protocols call for the total duration to be based on clinical factors. When patients are tolerating PO well, transition to oral antibiotics can be considered after 48–72 hours for a total 7–10 day course.

[Antibiotic Use for Appendicitis](#)

Discharge Criteria

Children with perforated appendicitis should be discharged home after a minimum of 48 hours of intravenous antibiotics and when clinically well (i.e., afebrile, ambulating, tolerating a diet, and with good pain control off narcotics).

Perioperative Anesthetic Considerations and Perioperative Medical Management

Intraoperative fluid requirements for children over 5 years

Intraoperatively, a child should have adequate IV access. If the appendix is found to be perforated, obtain a second IV prior to awaking from anesthesia. During surgery maintenance, isotonic crystalloid fluids (lactated ringers, normal saline, Plasma-Lyte) should be given.

[Perioperative Fluid Therapy in Pediatrics](#)

[Clinical Practice Guideline: Maintenance Intravenous Fluids in Children](#)

[Isotonic maintenance fluid: Practice Gap discussion at Update Course 2018](#) (Video)

Provide adequate resuscitation for perforated appendicitis, both preoperatively and intraoperatively

A child with perforated appendicitis requires IV fluid resuscitation. If they are significantly dehydrated from emesis and lack of oral intake, they may need significant resuscitation prior to going to the operating room. It is important to ensure that their alkalosis is corrected.

Start with a 20 cc/kg bolus of normal saline and monitor urine output. A second bolus may be needed, depending on the degree of dehydration. The maintenance fluid rate can be calculated using the Holliday-Segar Method: 4 mL/kg/hr for the first 10 kg, 2 mL/kg/hr for the second 10 kg, and 1 mL/kg/hr for every kg thereafter. If a child is dehydrated, start at $1.5 \times$ maintenance rate and continue to monitor urine output. A child under 6 years of age should have 1 ml/kg/hr of urine output if adequately resuscitated. A child over 6 should have at least 0.5 ml/kg/hr of urine output up to 30 ml/hr.

[Pediatric Fluid and Electrolyte Therapy](#)

Ensure antibiotics are timed appropriately prior to surgery

Children with appendicitis should be on therapeutic antibiotics and do not need specific preoperative or prophylactic antibiotics. Antibiotics should be started once a diagnosis of appendicitis is made and continued until the appendix is removed. If the appendix is not perforated, no antibiotics are needed after surgery. If a child goes to the operating room prior to receiving antibiotics, then the dose of antibiotics should be given within 60 minutes of making an incision. For those already being treated with antibiotics, the practice varies between institutions. It is reasonable to re-dose antibiotics immediately prior to incision, but it is not necessary.

[Antibiotics Versus Placebo for Prevention of Postoperative Infection After Appendectomy](#)

Provision of rapid sequence intubation in cases of acute appendicitis (including appropriate endotracheal tube size)

Rapid sequence intubation should be used for a child with acute appendicitis. They often have an associated ileus, along with nausea and vomiting, and are at a high risk of aspiration. The child is preoxygenated with 100% oxygen, and then an induction agent and neuromuscular blocking agents are given while cricoid pressure is gently held.

For a 2–10-year-old, typically a Miller 2 or Macintosh 2 blade is used. Size 3 is appropriate for most adolescents. The endotracheal tube (ETT) size can be estimated using $(\text{Age}/4) + 4$. The depth is typically $(\text{Age}/2) + 12$ or $\text{ETT size} \times 3$, ensuring that you listen to both lungs for adequate tube positioning.

[Pediatric Rapid Sequence Intubation](#)

Understand when awake extubation is required

General anesthesia with ETT intubation is generally used for laparoscopic appendectomy. Predictors of successful extubation include conjugate gaze, eye opening, facial grimace, purposeful movement, and spontaneous tidal volume > 5 mL/kg. Some anesthesia providers

prefer deep vs awake extubation. Deep extubation is the practice of removing the ETT when the airway reflexes related to oropharyngeal or glottic stimulation have been ablated. If a patient is extubated deep, they may have a higher incidence of coughing and desaturations in the recovery area or laryngospasm without a protected airway. In a resource-limited setting, an awake extubation may be safer.

[Extubation of Pediatric Patients Following General Anesthesia](#)

Appropriate sizing and placement of IV catheters vs central lines and NG vs OG tube sizes and placement

Once diagnosed with appendicitis, a child should have an IV placed. Central lines are rarely needed, but if a child is septic from perforated appendicitis, then this should be considered. If a perforated appendicitis patient has poor IV access, then central line placement can be considered in anticipation of lengthy IV antibiotic administration.

An orogastric tube should be placed for decompression of the stomach in the operating room. An NG tube should be left in place if there is high bilious output and visualized associated ileus from a bad perforated appendicitis. The NG tube size can be estimated using ETT size \times 2. Alternately, a length-based system such as the Broselow tape can be utilized as a guide.

[Pediatric Tube Sizes - Infographic](#)

A Foley catheter size can be estimated using ETT size \times 2. If a child does not urinate just prior to going to the operating room, then a Foley should be placed to decrease risk of injury to the bladder with trocar placement if a suprapubic trocar site is used. If there is concern for perforated appendicitis, a Foley can also allow for monitoring of the child's resuscitation.

[Pediatric Tube Sizes - Infographic](#)

[Bladder Injury in a Child During Laparoscopic Surgery](#)

Appreciate the benefits of multimodal analgesia in children with acute abdominal pain to include intraoperative local anesthetic blocks, ketorolac, IV Tylenol, and narcotics as needed

Most children do not need narcotics after a laparoscopic appendectomy for nonperforated appendicitis. Intraoperative local anesthetic blocks can assist with postoperative pain control. Local anesthesia can be given at port sites, or a transversus abdominis plane (TAP) block can be performed. A TAP block can be performed by anesthesia with ultrasound guidance or by the surgeon using laparoscopic guidance. Children should be discharged with alternating doses of ibuprofen and acetaminophen. In a child admitted for perforated appendicitis, IV ketorolac and IV Tylenol are effective non-narcotic pain medications.

[No Pain is Gain: A Prospective Evaluation of Strict Non-opioid Pain Control after Pediatric Appendectomy](#)

[Opioid Prescribing Habits of General Versus Pediatric Surgeons After Uncomplicated Laparoscopic Appendectomy](#)

Understand appropriate dosing of narcotics in pediatric patients, intraoperatively and in the PACU

It is imperative to ensure the correct dosing of narcotics for pediatric patients. The anesthesiologist will give narcotics as needed intraoperatively. In the PACU, narcotics may be necessary, and the child should have cardiopulmonary monitors in place. The pediatric dosing guidelines are below. One should start with the lowest dosing and be aware of maximum dosing. If an adolescent is adult size, then an adult dose may be less than a weight-based dose and should be used.

[Pediatric Medication Dosing Guidelines](#)

Understand the importance of temperature management in the operating room, and optimal ways to ensure this

The anesthesiologist should monitor the child's temperature throughout surgery. Axillary temperature or oral probes may be placed. If a Foley is placed, bladder temperature may be measured. A Bair hugger (forced-air warmer), if available, is helpful to adjust body temperature. Hypothermia should be avoided, as it can lead to increased morbidity, such as impaired wound healing. However, in a febrile patient, no warming techniques may be needed, and Tylenol may need to be given both to improve temperature and provide pain control.

[Perioperative Hypothermia in Children](#)

Management of Complications

Complications of appendectomy include the following, which will be discussed in more detail below:

[Bleeding](#)

[Wound Infection](#)

[Intra-abdominal Abscess](#)

[Bowel Obstruction](#)

[Bladder Injury](#)

Postoperative Bleeding Following Appendectomy

Postoperative bleeding is a rare complication following appendectomy. Bleeding may occur from the staple line/appendiceal stump or appendiceal mesentery.

Symptoms may include oliguria, tachycardia, hypotension, and abdominal pain. The initial workup includes CBC and ultrasound to evaluate for fluid collection.

Hemodynamically normal patients can be managed nonoperatively with serial hemoglobin/hematocrit. Operative management should be considered in patients with ongoing bleeding despite nonoperative management and/or hemodynamic instability.

Wound Infection Following Appendectomy

Laparoscopic appendectomy has a decreased risk of surgical site infection compared to open appendectomy. Obesity and perforated appendicitis are independent risk factors for surgical site infections.

Initial management includes local wound care, including drainage of any purulent material and appropriate antibiotic selection.

Intra-abdominal Abscess Following Appendectomy

Intra-abdominal abscess (IAA) is one of the most common complications encountered following appendectomy. IAA is most common following appendectomy for perforated appendicitis, occurring in 10–20% of cases. Postoperative antibiotics following appendectomy in the setting of perforated appendicitis will decrease the risk of IAA. The choice of appropriate antibiotics should be based upon institutional protocols and antibiograms.

Symptoms of IAA include abdominal distention, ileus, diarrhea, fever, and abdominal pain.

Initial management includes antibiotics and supportive care for the first 5–7 days postoperatively. If symptoms persist, then CBC, CRP, and imaging should be considered. Ultrasound is a useful initial diagnostic study to avoid radiation exposure. Initial imaging should occur at 5 to 7 days postoperatively to allow for the development of an abscess wall (rind) to differentiate an abscess from perioperative abdominal fluid.

Treatment includes continued antibiotics. A large abscess (> 3–5 cm in diameter) may require placement of an intra-abdominal drain. Consultation with interventional radiology for percutaneous drain placement should be considered. Consider transfer to a pediatric center if interventional radiology is not available.

Patients with large abscesses not amenable to percutaneous drainage may require surgical drainage, which can be done laparoscopically in many cases. If a fecalith is present in the abscess, every effort should be made to retrieve it.

[Image-Guided Percutaneous Drainage of Abdominal Abscessed and Fluid Collections](#) (Video)

[An Appendicular Abscess in a Child of About 9 Years](#) (Video)

Early Postoperative Bowel Obstruction Following Appendectomy

It is very common for children to have a significant ileus postoperatively following appendectomy for perforated appendicitis. This can persist for 10–14 days and be very difficult to distinguish from an early obstruction. In cases where bowel function does not return promptly, or when abdominal pain continues 2–3 days after surgery, a discussion with a pediatric surgeon at a children's surgical center should be considered regarding treatment considerations and the potential need for transfer.

Laparoscopic and open appendectomy are both associated with a small risk of early small bowel obstruction, with some studies suggesting a higher rate with an open approach. Risk factors for bowel obstruction include complicated/perforated appendicitis as well as surgical techniques, including the use of staples.

Initial management includes NPO, intravenous fluid resuscitation, and consideration of placement of an NG tube for enteric decompression. Children who are NPO for more than 5–7 days should generally be supported with TPN. As detailed above, children with significant gastric losses through NG tubes should have these losses replaced with 1/2NS with 20 mEq/L KCL.

Surgical management may be beneficial in patients who fail to respond to a period of nonoperative management.

Bladder Injury Following Appendectomy

Extraperitoneal bladder injury is a rare complication of laparoscopic surgery, commonly due to suprapubic trocar placement. **Voiding preoperatively** can decrease the risk of bladder injury, as can careful port placement, especially when placing a suprapubic port. Placement of ports lateral to the median umbilical ligaments should avoid injury to the bladder.

Symptoms may include dysuria, hematuria, lower abdominal pain, and oliguria.

Cystograms can identify the injury. Ultrasound and/or computed tomography may be useful.

Small extraperitoneal injuries may be managed nonoperatively with placement of a Foley catheter to drain the bladder for 5–7 days. Larger injuries or intra-peritoneal injuries may be managed operatively.

[Bladder Injury in a Child During Laparoscopic Surgery](#)

Conclusion

Pediatric appendicitis is commonly encountered by general surgeons and emergency medicine physicians working in all locations. Diagnosis can be difficult and treatment challenging, particularly in a remote area with limited resources.

The decision to transfer a patient to a referral center should weigh the severity of the disease and the availability of local resources and expertise against the impact on the family. In complex cases, early dialogue with a pediatric surgeon at a referral center is strongly recommended.