Pediatric Abdominal Pain

An Emergency Medicine Perspective

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KEYWORDS

• Functional constipation • Pyloric stenosis • Necrotizing enterocolitis • Appendicitis
• Incarcerated inguinal hernia • Gonadal torsion • Functional gastrointestinal disorder

KEY POINTS

- Avoid diagnostic momentum, especially when evaluating functional constipation and functional gastrointestinal disorders.
- Bilious vomiting in a neonate is a surgical emergency until proven otherwise.
- Always consider gonadal torsion in a child with lower abdominal pain.
- Do not overlook the potential for psychosocial causes of abdominal pain.
- Constipation is not an innocuous condition.

BACKGROUND

Pediatric abdominal pain is a common complaint evaluated in emergency departments (EDs). Although often due to benign causes, the varied and nonspecific presentations present a diagnostic challenge. Emergency care providers are tasked with the difficult job of remaining vigilant for the rare, yet devastating conditions while sorting through the much more common, benign causes of abdominal pain. This task is akin to finding the needle in the haystack. Diagnostic momentum can further threaten to divert the provider's attention from the true cause. Pediatric abdominal pain is a challenging complaint to evaluate and deserves specific attention.

EPIDEMIOLOGY

Overall, 5% to 10% of all ED visits by pediatric patients are for abdominal pain.[1,2] In the United States alone, up to 38% of school-aged children complain of abdominal

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pain weekly and up to 24% of them have had that pain for greater than 8 weeks.[3,4] What makes finding the rare, but potentially life-threatening case of abdominal pain even more difficult is that *only 5% to 10% of children* with abdominal pain have underlying organic disease and that the causes vary substantially with the age of the patients (**Table 1**).[3]

HISTORY

The history of present illness and past medical history are the foundation on which appropriate medical decisions are built. A thorough history helps pare down the large differential for abdominal pain. Although daunting in a busy ED, it is possible to obtain a thorough but efficient history.

When taking the history, question both the caregiver and child themselves separately, if age appropriate. Sitting or kneeling may help minimize anxiety in both children and parents. Interview the child where he or she is most comfortable. For older children and adolescents, a history for sexual activity, drug use, possible abuse, and suicidal ideation is best obtained with the caregivers out of the room.

PHYSICAL EXAMINATION

A complete history should always be followed by an equally thorough physical examination. Although the abdominal examination is the centerpiece, significant information can be gleaned from a full examination (**Box 1**). The patients' general appearance and activity level are also helpful in sorting out the potential causes, especially if infants are lethargic or inconsolable. Focusing only on the abdomen may lead to missing simple clues to other causes.

Table 1
Common causes of abdominal pain by age

Age	<1 y	1–5 y	5–12 y	>12 y
Common or benign	Colic, GERD, milk protein allergy	UTI, constipation	UTI, constipation, FGID, GAS	UTI, constipation, FGID, GAS
Urgent	AGE, malrotation without volvulus	AGE, HSP, pneumonia, Meckel diverticulum	AGE, IBD, pneumonia	AGE, IBD, pneumonia, hepatitis, pancreatitis, nephrolithiasis, PID
Emergent	Trauma, NAT, midgut volvulus, NEC, omphalitis, incarcerated hernia, pyloric stenosis, intussusception	Trauma, appendicitis, asthma	Trauma, appendicitis, gonadal torsion, DKA, asthma	Trauma, appendicitis, gonadal torsion, ectopic pregnancy, DKA, asthma

Abbreviations: AGE, acute gastroenteritis; DKA, diabetic ketoacidosis; FGID, functional gastrointestinal disorders; GAS, group A strep; GERD, gastroesophageal reflux disease; HSP, Henoch-Schönlein purpura; IBD, inflammatory bowel disease; NAT, nonaccidental trauma; NEC, necrotizing enterocolitis; PID, pelvic inflammatory disease; UTI, urinary tract infection.

Box 1
Physical examination for a child with abdominal pain

General

- Play with the child and engage him or her in a fun activity before the examination.
- Use a stuffed animal to show what you will do and how easy it is.
- Attempt to perform as much of the examination as possible in the caregivers lap if possible.
- Use a distraction during the examination.
- Use child life if they are available at your institution.

Constitutional

- Observation of the child before entering the room can direct your examination.
- Check for the absence or presence of a fever.
- Check for any other vital sign abnormality (ie, tachycardia, tachypnea, hypoxia).

Abdominal examination

- Use visualization for distention, masses, visible peristalsis, or bruising.
- Use auscultation for bowel sounds.

Palpation

- Check for the location of maximal tenderness, masses, or guarding.
- Having patients bend their knees while lying will help relax abdominal muscles and improve your examination.
- It is sometimes helpful to push with the stethoscope during auscultation to evaluate for tenderness.

Percussion

- It is possible to percuss for abdominal fluid.
- It can be helpful in evaluating for rebound tenderness.
- Asking patients to jump and give you a high 5 is a great way to assess for rebound tenderness.

Rectal

- This examination is not always necessary and *should not be routine* in all examinations.
- Directed reasons for a rectal examination are as follows: evaluate for bloody stool, possible fecal impaction, and question of Hirschsprung disease.

Genitourinary examination

- A genital examination should be performed in all male patients with abdominal pain and, at least, externally in all female patients.
- A complete gynecologic examination is sometimes required in sexually active female patients.

Remaining examination

- The remaining physical examination should not be skipped over.
- Evaluate for other causes of abdominal pain, such as pneumonia or pharyngitis.

IMAGING

Judicious use of imaging is often integral to a complete evaluation of abdominal pain. It is important to know the benefit and potential limitations of each modality. **Box 2** highlights some of the important considerations of various imaging modalities.

PEDIATRIC CAUSES OF ABDOMINAL PAIN

Constipation is a ubiquitous problem with a worldwide prevalence of 3% to 5%[6,7] (**Box 3**). In the United States, retrospective studies have shown constipation to account for 19.3% of all ED visits for abdominal pain and 0.4% of all visits to the ED.[1,7]

Box 2
Judicious use of imaging

Abdominal radiograph

- It is rarely useful because of low sensitivity and specificity.
- An acute abdominal series may show signs of obstruction or perforation.
- A fecalith in the right lower quadrant of a patient with appendicitis may occasionally be seen.
- It *should not be routinely* ordered for patients with constipation.
- It may show a basilar pneumonia.

Ultrasound

- It is often the image modality of choice for many diseases because it has no radiation exposure.
- It can be performed at the bedside.
- It may be very user dependent and is best at institutions that use it often.
- It is the imaging modality of choice for hydronephrosis from possible nephrolithiasis, gallstones, gonadal torsion, intussusception, pyloric stenosis, appendicitis, and Focused Assessment with Sonography in Trauma examinations.

Computed tomography

- It has high sensitivity and specificity for many intra-abdominal diseases.
- Sensitivity and specificity are often maintained between community and academic facilities.
- It exposes children to ionizing radiation.
  - 25.8 to 33.9 cases of solid organ cancer per 10,000 abdomen/pelvis CTs in girls[5]
  - 13.1 to 14.8 cases of solid organ cancer per 10,000 abdomen/pelvis CTs in boys[5]
- Children are more radiosensitive to ionizing radiation.
- Children have longer expected lifetime to manifest latent injury.
- There is greater potential for radiation overdose from inappropriate CT protocols.
- Helical computed tomography is the most sensitive test for nephrolithiasis in children.

MRI

- It has high sensitivity and specificity for many intra-abdominal diseases.
- It is expensive.
- It is time intensive.
- It is not readily available at many EDs.
- It may require sedation in children.

Box 3
Functional constipation

- Two or less defecations per week
- At least one episode per week of encopresis after potty training
- Excessive stool retention/retentive posturing
- Painful and hard bowel movements
- Large fecal mass in rectum or large-diameter stools that may obstruct toilet
- No pathologic cause

Data from Tabbers M, DiLorenzo C, Berger M, et al. Evaluation and treatment of functional constipation in infants and children: evidence-based recommendations from ESPGHAN and NASPGHAN. J Pediatr Gastroenterol Nutr 2014;58:258–74.

Diagnosis and Workup

Functional constipation is a diagnosis of exclusion, and the evaluation begins with a thorough history and physical examination.

Abdominal radiographs are often ordered to evaluate for constipation, but they only have a reported sensitivity of 60% to 80% and *should not be routinely ordered*.[6] In fact, there is no evidence to support routine testing of any sort if the child does not have any concerning signs or symptoms (**Box 4**), yet it is important to remain vigilant for other concealed conditions, such as Hirschsprung disease in the neonate with constipation.

Management

The management of constipation can be broken up into 2 groups: *ED management* and *home management*. The cornerstone of ED management for constipation begins with setting reasonable expectations and explanation that this is a long-term process. An enema in the ED may be required, but daily osmotic laxatives (eg, polyethylene glycol 3350) or glycerin suppositories at home, behavioral modifications, and close follow-up with their primary care provider will keep them out of the ED.

PYLORIC STENOSIS

- The pylorus is a single unit of smooth muscle at the lower end of the stomach.
- It connects to the duodenum via the pyloric sphincter.
- Stenosis occurs with elongation and thickening of the pylorus.

Box 4
Important aspects of the physical examination for constipation

- Growth parameters (ie, look at their growth chart for failure to thrive)
- Abdominal distention and the presence of a fecal mass
- Soiling of their undergarments or skin in the perianal area
- Anal skin tags, anal fissures or tears, flat buttocks, or a sacral dimple/tuft of hair
- Complete neurologic examination with deep tendon reflexes and evaluating for saddle anesthesia
- No evidence for routine digital rectal examinations unless concern for an organic cause or unsure diagnosis[6,8]

Gastric outlet obstruction occurs when the pyloric sphincter is unable to open.

Pyloric stenosis is the most common surgical cause of nonbilious emesis in infants less than 6 months of age and typically occurs around 4 to 6 weeks.[9–11] Up to 43% of patients with pyloric stenosis are firstborn, and it is 4 to 5 times more common in males.[10–12]

Diagnosis and Workup

Any infant with true vomiting is concerning and deserves a thorough evaluation. Most clinicians will easily recognize the classic presentation of pyloric stenosis; however, not every presentation is classic. The physical examination can heighten suspicion for pyloric stenosis as well as help sort through other causes of vomiting.

If the infant has worsening projectile vomiting or failure to thrive, diagnostic testing to evaluate for pyloric stenosis should be done.

- Laboratories
  - Classically, infants develop hypochloremic hypokalemic metabolic alkalosis.
  - With earlier diagnosis, less than 50% of infants will present with electrolyte abnormalities.[13,14]
  - Electrolyte changes often after vomiting for greater than 1 week.[13]
- Abdominal ultrasound
  - It is the imaging modality of choice with a sensitivity of 98% to 100% and specificity up to 100%.[9,15]
  - Findings are consistent with pyloric stenosis: pylorus length greater than 14 to 17 mm and a single-wall thickness greater than 3.0 to 4.5 mm[9,13,16] (**Fig. 1**).
  - ED physicians using point-of-care ultrasound had 100% sensitivity (95% confidence interval [CI] 66%–100%) and 100% specificity (95% CI 92%–100%) when able to identify the pylorus (wide CIs for sensitivity makes this a nonideal screening test).[9]
- Upper gastrointestinal (GI) study
  - It is the former gold standard, but rarely used now.[15]
  - It is useful if bilious vomiting is present as it also evaluates for malrotation and volvulus.[10,15]

Fig. 1. Length 25.1 mm, thickness 5.8 mm. (*From* Shah S. An update on common gastrointestinal emergencies. Emerg Med Clin North Am 2013;31:775–93.)

- Findings are as follows:
  - String sign: a string of contrast through the elongated pyloric channel
  - Double-track sign: several linear tracks of contrast separated by redundant mucosa
- Abdominal radiographs
  - It is rarely useful but may show gas in the stomach and a paucity distal to the pylorus.

Management

These infants may present ill appearing and may require stabilization with fluid resuscitation. It may be difficult to differentiate between sepsis and pyloric stenosis in a severely dehydrated infant, and a sepsis evaluation may be necessary as well. Once volume resuscitated and stable, surgical correction is required. Being mindful of the management will ideally help avoid potential pitfalls (**Box 5**).

INTUSSUSCEPTION

- Telescoping of one portion of intestines into itself
- Most common cause of GI obstruction in children
- Second most common abdominal surgical emergency in children

Intussusception is the most common cause of GI obstruction in children and is the second most common pediatric acute abdominal surgical emergency. Its peak incidence is at 5 to 10 months of age.[17–19]

Diagnosis and Workup

Often the need for evaluation will be predicated on the history and a high index of suspicion. The classic history of colicky abdominal pain interspersed with episodes of normal activity or lethargy is seen in only 7.5% to 50.0% of patients.[17,20,21] It may even be painless in up to 40% of patients less than 4 months of age.[22] Red currant jelly stools represents bowel ischemia. Up to 75% of children without these grossly bloody stools may still be hemoccult positive.[23]

- Using history and examination alone, physicians are better at determining patients who do not have intussusception rather than who do (specificity of 85% and an negative predictive value of 94%).[21]
- Laboratory evaluation is often unnecessary, although abnormalities like leukocytosis, elevated band count, and elevated lactate can be seen with bowel perforation.[24]

Abdominal radiographs

- A paucity of gas in the right lower quadrant, intracolonic mass, rim sign, or signs of small bowel obstruction may be seen.

Box 5
Pitfalls of pyloric stenosis

- Failing to perform a comprehensive history and physical in every vomiting infant
- Ruling out pyloric stenosis automatically in an infant with bilious vomiting
- Deciding an infant does not need a full diagnostic workup for pyloric stenosis because they do not have an olivelike mass or hypochloremic hypokalemic metabolic alkalosis
- Forgetting to check a glucose level in a child with severely altered oral intake

- Overall sensitivity for ileocolic intussusception is 74% to 90% and is 88% to 100% sensitive if there is air in the ascending colon in all images of a 3-view abdominal radiograph.[17,25]
- *Up to 24% of children with intussusception may have normal radiographs*.[26]

Abdominal ultrasound

- Evaluate for a target, donut, or pseudokidney sign (**Fig. 2**).
- In the radiology department, ultrasound has a 97.9% to 100% sensitivity.[25]
- One study showed ED physician point-of-care ultrasound to have a sensitivity of 85% and specificity of 97%.[19]

Abdominal computed tomography/MRI

- Rarely necessary and is not cost-effective
- May be necessary to identify a pathologic lead point in an older child or for recurrent intussusception

Fluoroscopy enema

- Diagnostic and therapeutic for intussusception
- Avoid if you have a concern for peritonitis, perforation, or necrosis

Management

Once diagnosed, the intussusception must be reduced. The largest controversy associated with intussusception management has to do with final disposition. It is common for most hospitals to admit and observe children after successful nonoperative reduction because of the 7.5% to 43.0% recurrence rate.[18,27] A recent meta-analysis showed that 2.2% to 5.3% of patients had a recurrence at 24 hours and 7.1% at 48 hours.[18,28] After 48 hours, recurrence was seen in 5.1% and there was rarely adverse events.[26] This finding, along with a growing body of supportive evidence,

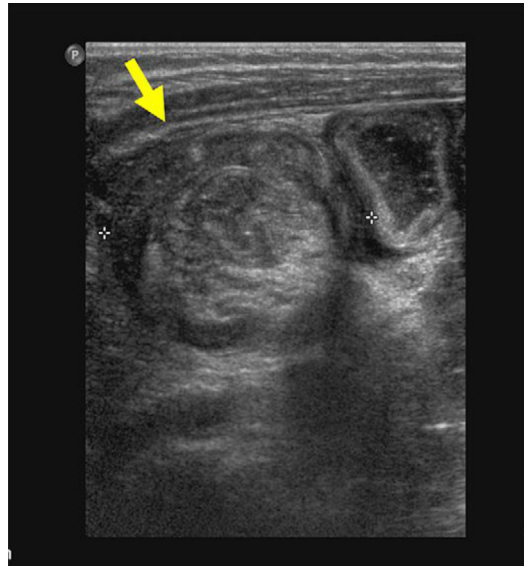

Fig. 2. Sonographic image showing the target or donut sign associated with intussusception. (*From* Marin J, Alpern E. Abdominal pain in children. Emerg Med Clin North Am 2011;29:401–28.)

has led many practitioners to begin observing patients for approximately 6 hours after successful nonoperative reduction and then discharging home with strict return precautions and close follow-up.[18,27,28] Naturally, disposition planning requires coordination with the pediatric surgical team to help avoid potential pitfalls (**Box 6**).

MALROTATION WITH OR WITHOUT MIDGUT VOLVULUS

- Malrotation refers to a spectrum of abnormal rotation of the duodenum around the superior mesenteric artery (SMA) axis.
- This abnormal rotation leads to a shortened mesenteric root and predisposes to midgut volvulus.
- Additionally, fibrous peritoneal bands (ie, Ladd bands) can lead to volvulus or obstruction themselves.

Midgut volvulus is abnormal rotation and fixation of the midgut around the SMA axis that impedes lymphatic drainage, venous outflow, and arterial blood flow leading to massive bowel infarction.

Although malrotation is traditionally thought of as a disease of infancy, up to 25% of patients may not be diagnosed until 5 years of age.[29] Sixty percent of patients with malrotation, however, will present by 1 month and *90% with volvulus present within the first year of life*.[22,30,31]

Diagnosis and Workup

Bilious vomiting is present in greater than 90% of neonates with volvulus and should always be considered a surgical emergency until proven otherwise.[32] Neonates with volvulus are typically irritable because of poor feeding with vomiting, abdominal pain and/or distention, and hematochezia. Older children with bilious vomiting have a larger differential diagnosis, but there should always be a high index of suspicion for malrotation with volvulus because 22% of children and 12% of adults with malrotation present with a volvulus.[32] They will often have a history of chronic abdominal pain or cyclic vomiting and present with abrupt worsening of abdominal pain, and 50% will have nonbilious vomiting.[30]

Naturally, any patient with signs of decompensation requires aggressive resuscitation before further diagnostic testing. Surgical consultation may be required based solely on clinical suspicion if the child remains unstable with findings concerning for abdominal catastrophe. Once the child is stable, imaging should be performed to evaluate for malrotation and volvulus.

- Abdominal radiograph
  - It is often the initial study of choice because it is quick and readily available.
  - Findings are as follows:
    - Double bubble sign signifying duodenal obstruction
    - Lack of bowel gas distal to the duodenum

Box 6
Pitfalls of intussusception

- Not considering and evaluating for a possible pathologic lead point in an older child with intussusception or in cases of recurrence
- Failing to recognize that intussusception can lead to somnolence and lethargy
- Missing the diagnosis because the infant had fever, anorexia, or diarrhea initially

    - Bowel malposition
    - Air fluid levels
    - Pneumatosis
    - The most common finding is “normal bowel gas pattern.”[33]
- Upper GI with small bowel follow-through
    - It is considered the gold standard and defines size, shape, rotation, and presence of obstruction.
    - Malrotation with or without volvulus is suggested if the duodenal-jejunal junction (DJJ) is in low position, DJJ is not left of the vertebral body pedicle, the jejunum is on the right and coiled like a spring, there is duodenal redundancy, or there is a corkscrew appearance of the DJJ (**Fig. 3**).
    - Sensitivity is 93% to 100%, but the false-positive rate is 15% and false-negative rate is 2% to 3%.[34]
    - Equivocal findings are seen in up to 37% of patients.[35]
- Ultrasound
    - Normally, the superior mesenteric vein (SMV) should be right of the SMA.
    - With malrotation, the SMV will be anterior or leftward or the duodenum will not be between the SMA and aorta.
    - If volvulus is present, a whirlpool sign, whereby the SMV wraps around the SMA on color-flow Doppler, may be seen.
    - There is a clinical spectrum of normal variant anatomy, and confirmatory testing is often still necessary.
- Other imaging modalities
    - *Barium enema* may show the cecum in the right upper quadrant or in the central abdomen but is not a reliable sign for malrotation.
    - *Abdominal CT* can evaluate the anatomic relationship between the SMA, SMV, and DJJ positioning with a sensitivity of 97.3% and specificity of 99.0%.[33]
    - *Abdominal MRI* can identify malrotation as well but is often time and cost prohibitive.

Fig. 3. Upper GI series demonstrates inferior displacement of the DJJ to the right. DJJ does not pass to the left of the spine and does not rise to the level of the duodenal bulb. Proximal small bowel appears on the right side of the abdomen. Likely corkscrew pattern of duodenum indicating volvulus. (*From* Shah S. An update on common gastrointestinal emergencies. Emerg Med Clin North Am 2013;31:775–93.)

Management

Management of malrotation depends on the presence of an associated midgut volvulus. Midgut volvulus is a true surgical emergency. Immediate surgical consultation and operative repair with a Ladd procedure is necessary. Aggressive resuscitation and correction of hypoglycemia is imperative. Additionally, gastric decompression and initiation of broad-spectrum antibiotics that cover gut flora are vitally important. Unfortunately, even with prompt resuscitation and emergent surgical correction, the mortality rate for a midgut volvulus is 3% to 9%. Asymptomatic pediatric patients with malrotation but no midgut volvulus can be managed electively by pediatric surgery (**Box 7**).

NECROTIZING ENTEROCOLITIS

- Classic triad of abdominal distention, GI bleeding, and pneumatosis on radiograph
- Modified Bells staging: stage I suspected necrotizing enterocolitis (NEC), stage II mild NEC, and stage III severe NEC

NEC is often thought of as a disease of prematurity, but nearly 10% to 13% of neonates with NEC are full term within the first 10 days of life.[36,37] Presentation can vary from being nonspecific with temperature instability and feeding intolerance to overt shock with grossly bloody stool. Often times, full-term NEC is associated with infection, hypoxic event at birth, congenital heart disease or cardiac surgery, and umbilical artery catherization.[37]

Diagnosis and Workup

Full-term NEC can often present in a nonspecific fashion, and the clinician needs to maintain a high index of suspicion while sorting through the other potential diagnoses.

Because these patients will often appear similar to a septic neonate, a full septic workup including glucose level, complete blood count, comprehensive metabolic panel, urinalysis, blood and urine cultures, and cerebrospinal fluid (CSF) studies is beneficial. An abdominal radiograph, with either a cross-table lateral or decubitus view, may show an abnormal gas pattern, pneumatosis, free air, or portal gas. Abdominal ultrasound may show a pseudokidney sign. Additional studies are often required to evaluate for uncommon causes of NEC in a full-term neonate.

Management

These patients can become critically ill rapidly and may require cardiopulmonary and fluid resuscitation. Twenty percent to 30% of neonates with NEC have bacteremia,

Box 7
Pitfalls of malrotation with or without volvulus

- Not appreciating that an infant with bilious vomiting is a surgical emergency until proven otherwise
- Delaying surgical consultation by obtaining time-intensive testing in an acutely ill neonate/child with a suggestive history of malrotation with volvulus
- Dismissing the idea of malrotation with volvulus in a worrisome child because imaging was negative
- Always be vigilant of patients with chronic abdominal pain and vomiting who have been labeled cyclic vomiting—avoid diagnostic momentum because they patients may be an older patient with undiagnosed malrotation.

and broad-spectrum antibiotics (eg, ampicillin + cefotaxime + metronidazole) that cover gut flora should be initiated promptly. The neonate should have nothing by mouth, and a nasogastric tube should be placed for gastric decompression. Early coordination with pediatric surgery is necessary. Neonates with pneumoperitoneum, an abdominal mass or stricture with obstruction, or signs of sepsis require operative intervention[37] (**Box 8**).

APPENDICITIS

- It is inflammation of the appendix.
- It can affect all age groups but is difficult to diagnosis in the very young.
- Children less than 3 years of age have the highest perforation risk.

Appendicitis is the most common pediatric surgical emergency, and 250,000 cases are seen annually with a lifetime risk of developing it of 8.6% for men and 6.7% in women.[38–40] The perforation rate is 80% to 100% in children younger than 3 years and up to 38% in older children.[24,41]

Diagnosis and Workup

The diagnosis of appendicitis may be quite clear or rather confounded but typically involves a combination of physical examination findings, laboratories, and imaging.

- History and physical examination
  - Studies have shown experienced practitioners in pediatric emergency medicine are able to accurately diagnose men with appendicitis at a rate of 78% to 92% and women at 58% to 85%.[42]
  - Unfortunately, physical examination alone leads to a false-negative rate of 9.8% when taken to the operating room (OR) directly based on examination as opposed to 4.5% with imaging.[43]
  - Overall, there is no single predictor highly indicating appendicitis; but rebound tenderness has a positive likelihood ratio (LR) of 2.3 to 3.9, and right lower quadrant (RLQ) pain to percussion has a positive LR of 2.56.[24,44]
  - As always, being mindful of the other potential causes of abdominal pain is necessary.
- Laboratory values
  - A complete blood count (CBC) with differential is often ordered but has relatively low diagnostic yield. If it is greater than 10,000 mm^3 it has a positive LR of 1.77 and a sensitivity and specificity for appendicitis of 65% to 85% and 32% to 83%, respectively.[44,45]
  - Increased polymorphonuclear cells and bandemia may provide diagnostic clues but are not indicative by themselves.
  - A C-reactive protein (CRP) greater than 10 mg/L is not sensitive or specific for appendicitis but may be a strong predictor of perforation.[46]

Box 8
Pitfalls of NEC

- Failing to consider NEC as a possible diagnosis for abdominal pain in a full-term neonate
- Not searching for uncommon causes associated with NEC in a full-term neonate, such as congenital heart disease (eg, coarctation or patent ductus arteriosus)
- Forgetting that sepsis may cause NEC and a full workup including CSF is needed
- Not stopping feeds and starting antibiotics when you suspect NEC

- Pooled laboratory tests may increase the predictive power and generate a sensitivity of 98% to 99%, but they still have low specificity (only 6%–12%).[45]
- Overall, laboratory test results may help determine which patients are at low risk for appendicitis, but they do not help determine who actually needs to go the OR for an appendectomy.
- A pregnancy test in female patients should always be done.

- Imaging
  - Abdominal radiographs are rarely useful, showing an appendicolith less than 5% of time.[42]
  - Abdominal ultrasound is often used as the first imaging of choice when evaluating appendicitis (**Fig. 4**)
    - It has become the imaging modality of choice at many institutions and is recommended by the American College of Emergency Physicians to *diagnose but not exclude*.[47]
    - It has a sensitivity of 72.5% to 94.0% and specificity of 89% to 98% when the appendix is visualized (25%–73% of the time).[48,49]
    - False negatives can be seen with perforation or tip appendicitis.[50]
    - The diagnostic accuracy increases with the duration of symptoms.[49]
  - Abdominal computed tomography (CT) may be used when abdominal ultrasound was non-diagnostic for appendicitis or other diagnoses are being considered concurrently.
    - It is the imaging modality of choice for many institutions because it has a sensitivity of 90% to 97% and specificity of 91% to 99%.[25,51]
    - This high accuracy is maintained between large academic hospitals and small rural community hospitals.[38]

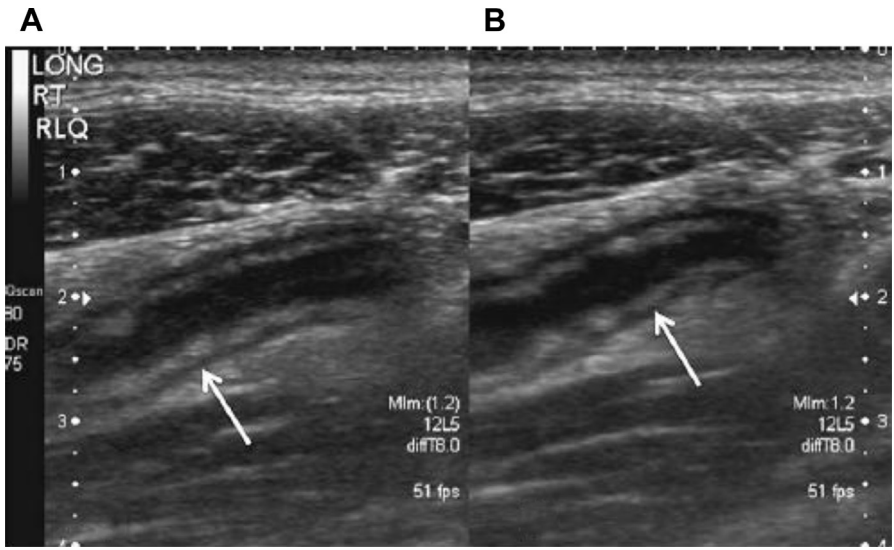

Fig. 4. Thickened wall, noncompressible. (*A*) Sonographic image of appendix without compression. (*B*) Sonographic image of appendix with compression showing noncompressible appendix. Sonographic image of the thickened wall of the appendix with appendicitis (*arrow*). (*From* Parks N, Schroeppel T. Update on imaging for acute appendicitis. Surg Clin North Am 2011;91:141–54.)

        - Unfortunately, children are much more sensitive to the ionizing radiation and have a lifetime radiation-induced cancer risk of 20.1 to 26.1 per 100,000.[52]
    - Abdominal MRI has 100% sensitivity and 96% specificity without radiation exposure but is not readily available in all EDs.
- Scoring systems
    - The Alvarado scoring system was initially designed to use in adults but only has a specificity of 59% to 100% in children.[53,54]
    - The Pediatric Appendicitis Score was designed specifically for children but again has a specificity range of 50% to 98%.[54,55]
    - The a priori judgment of experienced practitioners in emergency medicine has a specificity of 49.6% to 90.2% *and is equal* to these appendicitis scoring systems.[44]
    - Scoring systems seem to be most useful for trainees or as adjuncts to optimize and standardize patient management.[44]

Management

The primary challenge for the emergency care provider is in considering and diagnosing appendicitis. Its subsequent ED management is relatively straightforward as long as potential pitfalls are appreciated (**Box 9**).

INCARCERATED INGUINAL HERNIA

- It is entrapment of peritoneal contents in an inguinal hernia.
- Strangulation occurs when the hernia is tightly constricted and the vascular supply of the herniated contents becomes severely compromised.

Inguinal hernias are the *most common congenital abnormality that requires surgery* occurring in 0.8% to 4.4% of the general population but up to 6% to 31% in pediatric patients.[56,57] It is 6 times more common in males and typically occurs on the right side.[58]

Diagnosis and Workup

Incarcerated inguinal hernias are often diagnosable with history and physical examination alone, which has a sensitivity of 84%.[56] They typically present with an abrupt bulge in the groin area that increases in size when the child is upset and disappears when calm. The child is usually comfortable appearing unless it is incarcerated. If incarcerated, the hernia is not easily reduced and the child is inconsolable. Bloody stools and bilious emesis occur with bowel strangulation.

Bedside point-of-care ultrasound can augment the evaluation. If a hernia is present, peristalsis with air or fluid within the lumen of the inguinal mass will be seen.

Box 9
Pitfalls of appendicitis

- Assuming a child who has a concerning examination does not have appendicitis because of a negative or indeterminate ultrasound
- Not ensuring adequate follow-up within 24 hours for children discharged home with a worrisome history but reassuring laboratory test results/imaging
- Failing to consider gonadal torsion in any child with lower abdominal pain and concern for appendicitis
- Relying on only one sign or symptom to diagnose or exclude appendicitis

Ultrasound in the radiology department has a sensitivity of 97.9% and can help differentiate between indirect and direct hernias.[56] Formal sonographic evaluation should be considered in female patients to evaluate for ovarian contents.

Management

Nonoperative management of incarcerated hernias with bedside reduction requires adequate analgesia and possibly sedation (50% of children do not receive analgesia before this procedure).[59] If bedside reduction fails, pediatric surgical consultation with possible operative repair is necessary (**Box 10**).

GONADAL TORSION

- Ovarian torsion
  - It is a rotated ovary on its pedicle leading to obstruction of venous outflow, lymphatic drainage, and arterial blood flow once the ovary is engorged and edematous.
  - Adnexal torsion occurs with torsion of the ovary and/or fallopian tube.
- Testicular torsion
  - It is the rotation of spermatic cord resulting in compromise of testicular blood flow.

Ovarian torsion accounts for up to 2.7% of all cases of acute abdominal pain in female patients, but only 15% of those are in children.[60,61] Forty percent to 84% of cases of ovarian pathology have some abnormal features upon histologic examination but this is rarely malignancy.[62]

Testicular torsion occurs in 3.8 to 4.5 males per 100,000, but only 3% to 38% of males with acute scrotal pain have testicular torsion.[61–64] A bell-clapper deformity is a predisposing condition for torsion and occurs bilaterally in 12% of patients who develop testicular torsion.[62]

Diagnosis and Workup

Whether it is a female or male patient being evaluated, early diagnosis and a high clinical suspicion is important for gonadal salvage. There are obvious differences between their respective diagnostic evaluations.

Ovarian torsion

- Diagnosis is difficult because of the nonspecific symptoms often seen, and up to 38% are initially diagnosed with appendicitis.[65]
- Colicky RLQ pain is common with associated fever, nausea, vomiting, and dysuria.
- A previous history of torsion or ovarian mass is often seen.
- On average, girls wait 2.5 times as long for imaging and 2.7 times as long to go to the OR as males with testicular torsion.[66]

Box 10
Pitfalls of incarcerated inguinal hernia

- Failing to consider ovarian involvement in female patients
- Not providing adequate analgesia and sedation before nonoperative reduction
- Failing to evaluate for testes below the hernia, that is, not a retracted testicle

Box 11
Pitfalls of gonadal torsion

- Only looking at the appendix in female patients with a concerning history—historically leads to ovarian salvage rates of 9% to 50%[67]
- Not maintaining a high clinical suspicion for ovarian torsion in female patients with RLQ abdominal pain
- Ruling out gonadal torsion based on there being normal blood flow on color Doppler
- Not performing a testicular examination on all males with abdominal pain

- Laboratory values are nonspecific, but urinalysis and urine pregnancy tests should be performed.
- A pelvic ultrasound has a sensitivity of 100% and specificity of 98% for ovarian torsion and will often reveal an enlarged adnexal mass or ovary with a whirlpool sign.[60,67]
- Color Doppler sonography is useful, but up to two-thirds of cases will have arterial blood flow because the *ovary is fed by both the ovarian and uterine arteries* (**Box 11**).[60,61]
- The presence of pelvic mass or an ovarian cyst greater than 5 cm is 83% sensitive for ovarian torsion.[60]
- It is useful to ultrasound the appendix at the same time because they have similar presentations.
- It is important to note that nonsexually active and prepubescent girls require a transabdominal ultrasound with a full bladder, whereas older, sexually active females require a transvaginal ultrasound with an empty bladder.
- Abdominal/pelvic CT may see an adnexal mass or other abdominal pathology but does not rule in ovarian torsion.
- Overall, diagnosis takes a high index of suspicion, a consistent history and examination, and only sometimes an abnormal sonographic finding.

Testicular torsion

- High position of the testicle and abnormal cremasteric reflex have an odds ratio of 58.8 and 27.7, respectively, for testicular torsion.[63]
- Pain less than 24 hours with associated nausea/vomiting increase the likelihood of testicular torsion if they have an acute scrotum.[63]
- Testicular ultrasound is the most used imaging modality and has a sensitivity of 88% to 96% and specificity of 78% to 98%.[62,64]
- It may reveal a torsion knot in the spermatic cord, which has 96% to 99% sensitivity and specificity for testicular torsion.[62,68]
- If blood flow is present, the testis is more likely to be salvageable with emergent reduction and orchidopexy (**Box 12**).

Box 12
Functional GI disorder

- Chronic abdominal pain in the absence of organic disease
- Possibly related to dysregulation of the brain-gut axis expressed by visceral hypersensitivity
- 3 major subsets: functional dyspepsia, functional abdominal pain, and irritable bowel syndrome

Box 13
Important aspects of the history for FGID

Functional abdominal pain

- Episodic or continuous periumbilical abdominal pain

IBS

- Diffuse abdominal pain
- Related to bowel movement frequency and improves after defecation

Functional dyspepsia

- Nausea
- Vomiting
- Symptoms consistent with gastroesophageal reflux disease

General

- Often have anxiety, depression, social isolation, and school absenteeism[71]
- Family history of celiac disease, IBD, peptic ulcers, FGID, and constipation

Functional GI disorder (FGID) is a common worldwide problem with a prevalence of 1.6% to 41.2%. Up to 45% of these children will be diagnosed with irritable bowel syndrome (IBS).[69,70] Seventy percent of diagnosed cases of IBS occur in females, but there is more sex variability with the other subsets of FGID.[69,71] It is no surprise that this entity is the most common disease leading to consultation with a pediatric gastroenterologist.[72]

Diagnosis and Workup

The American Academy of Pediatrics recommends that evaluation for FGID should take place in the primary care setting, but these children will often present to the ED.[3] When they do, a full history and physical examination (**Box 13**) should be performed to ensure that there are no red flags for organic disease, abuse, depression, or suicidal ideation (**Box 14**).

If they have a reassuring history and physical examination, diagnostic testing is often low yield.[3] If there are red flags on examination, laboratory values, such as CBC, CRP, liver function tests, lipase, erythrocyte sedimentation rate, celiac serologies, urinalysis, urine pregnancy test, and stool studies, may be indicated. Imaging though is not routinely recommended. Without a concerning red flag, less than 1%

Box 14
Red flags for organic cause of abdominal pain in children

- Weight loss
- Severe vomiting
- Chronic severe diarrhea
- GI bleeding
- Hematemesis
- Fever
- Family medical history of inflammatory bowel disease

Box 15
Pitfalls of FGID

- Not considering psychosocial conditions like depression, suicidal ideation, or child abuse in your differential—this may be how the child is reaching out for help
- Failing to recognize and workup worrisome red flags associated with FGID
- Failing to perform a thorough examination in child already labeled with chronic abdominal pain

of children will have an abnormality on ultrasound.[3] If further workup is needed, but children are stable and there is not concern for an emergent condition, the need for evaluation should be explained and then deferred to patients' primary care provider.

Management

The mainstay of management for children with FGID is thorough anticipatory guidance discussions and the setting of reasonable expectations (**Box 15**).

SUMMARY

Up to 10% of all visits to a pediatric ED are for abdominal pain.[48] The astute clinician needs to have a high index of suspicion while evaluating any child with abdominal pain. The challenge is to remain vigilant for the rare, yet significant pathologic condition, while not overtesting the more common, benign conditions.

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