Acute appendicitis in children: Diagnostic imaging

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INTRODUCTION

This topic will review diagnostic imaging for acute appendicitis in children. The epidemiology, clinical features, diagnosis, and treatment of appendicitis in children and the evidence regarding the risk for malignancy associated with ionizing radiation during abdominopelvic computed tomography (CT) in children with appendicitis are discussed separately:

- (See "Acute appendicitis in children: Clinical manifestations and diagnosis".)
- (See "Acute appendicitis in children: Management".)
- (See "Radiation-related risks of imaging", section on 'Children and adolescents'.)

WHO TO IMAGE

The decision to perform imaging in the diagnostic evaluation of children with abdominal pain is determined by clinical findings as follows (algorithm 1) (see "Acute appendicitis in children: Clinical manifestations and diagnosis", section on 'Clinical suspicion'):

- **Low risk of appendicitis** – Imaging is **not** warranted in most children who have a low risk of appendicitis based upon the clinical examination and laboratory studies if obtained, or who have an alternative condition that explains their abdominal pain (eg, streptococcal pharyngitis or pneumonia).
- **Moderate risk for appendicitis** – For children who have a moderate risk for appendicitis on physical examination, imaging can help establish or exclude the diagnosis. For these

patients, we prefer ultrasonography (US) for initial imaging of the appendix. (See 'Approach (moderate risk of appendicitis)' below.)

Patients with a moderate risk of appendicitis include those with a Pediatric Appendicitis score 3 to 6 (table 1) or similar constellation of findings with or without use of another clinical score and, if obtained, laboratory studies; imaging is also appropriate for patients who have received antibiotics and may have masking of signs and symptoms prior to evaluation.

In settings where operative care for children with appendicitis is **not** available, resources for appropriate pediatric imaging and interpretation of radiographic findings may also be lacking [1]. Clinicians managing patients with suspected appendicitis in these settings should contact a pediatric surgeon prior to imaging or treatment whenever possible. In general, imaging (especially CT scan) should be avoided prior to transfer.

- **High risk for appendicitis** – We prefer that children with a high risk of appendicitis based upon clinical findings undergo evaluation by a surgeon with pediatric expertise prior to diagnostic imaging. If imaging is performed prior to surgical evaluation, we advise US rather than CT.

A systematic institutional approach to the choice of imaging is associated with improved outcomes including reduced radiation exposure, increased diagnosis of appendicitis at initial presentation, decreased negative appendectomy rate (NAR), and no increase in perforation rate. (See 'Clinical protocols' below.)

Clinical scoring systems have the potential to help with decisions regarding diagnostic imaging and limit the use of imaging in children with a low risk of appendicitis. (See "Acute appendicitis in children: Clinical manifestations and diagnosis", section on 'Clinical scoring systems'.)

APPROACH (MODERATE RISK OF APPENDICITIS)

Our approach to diagnostic imaging in children with suspected appendicitis is consistent with the American College of Radiology [2]. For children with a moderate risk of appendicitis (eg, Pediatric Appendicitis score 3 to 6 (table 1) or similar constellation of findings with or without use of another formal clinical score), we prefer ultrasonography (US) as the initial imaging study. Further management depends upon ultrasound findings:

- **Ultrasound negative** – If the appendix is visualized on ultrasound and shows no sign of appendicitis, then no further initial imaging is needed because the diagnostic accuracy of ultrasonography (US) when the appendix is visualized is equivalent to computed tomography (CT) or magnetic resonance imaging (MRI). (See 'Diagnostic performance' below and 'Sonographic findings' below.)

The clinician should review the patient's findings and determine the need to evaluate for other serious causes of abdominal pain (table 2 and algorithm 2 and algorithm 3). (See "Emergency evaluation of the child with acute abdominal pain".)

Children with a clear alternative diagnosis should undergo specific treatment for the identified condition.

Although the risk is low, patients without an obvious alternative diagnosis for abdominal pain may still have appendicitis. If discharged, the clinician should inform the parents/primary caregivers that appendicitis, although much less likely, is still possible and provide clear instructions to return if abdominal pain increases or becomes localized to the right lower quadrant (RLQ). (See "Acute appendicitis in children: Clinical manifestations and diagnosis", section on 'Clinical suspicion'.)

- **Ultrasound positive** – Patients with findings of appendicitis on ultrasound should undergo evaluation by a surgeon with pediatric expertise. Given the high sensitivity and specificity of US for appendicitis, these patients typically undergo appendectomy without further imaging. (See 'Diagnostic performance' below and 'Sonographic findings' below.)

- **Ultrasound nondiagnostic** – If the appendix is not visualized and the findings on ultrasound are otherwise not diagnostic, options include (see 'Sonographic findings' below):

  - **Observation** – Admit the patient for observation and perform serial reassessment (eg, every four to eight hours). If the diagnosis remains in question after 12 to 24 hours, in addition to physical examination findings, a repeat complete blood count with differential and C-reactive protein may help the surgeon make or exclude a clinical diagnosis of appendicitis.

    If a clinical diagnosis of appendicitis cannot be made and concerning clinical features persist, repeat US or perform MRI or CT. When available, repeat US or MRI is preferred rather than CT to avoid radiation exposure.

    In the United States, increased use of US alone or US with MRI or CT has been associated with lower rates of negative appendectomy without an increase in appendiceal rupture or patients returning with a new diagnosis of appendicitis within two weeks of initial emergency department visit [3-7].

    In patients whose initial ultrasound is not diagnostic for appendicitis, repeat physical examination and a second ultrasound in patients who have persistent findings of appendicitis has good diagnostic accuracy and can markedly reduce the number of children undergoing MRI or CT. For example, in a prospective observational study of 294 children undergoing acute evaluation for abdominal pain (38 percent with appendicitis), a pathway that utilized serial physical examination, surgical consultation, and repeat US for patients whose initial US was nondiagnostic achieved a sensitivity of 97 percent and a specificity of 91 percent [8]. CT was performed in four patients.

- **Image with a different modality** – If a clinical diagnosis of appendicitis cannot be made and a more prompt diagnosis is desired based upon the surgeon's shared decision-making with the family/caregivers, perform an MRI or CT. (See 'Magnetic resonance imaging' below and 'Techniques' below.)

  In settings with adequate experience in interpreting MRI for the presence of appendicitis and with the resources to rapidly obtain and interpret the study, we prefer MRI rather than CT. Evidence suggests that the use of MRI is associated with similar diagnostic accuracy and negative appendectomy rates (NARs). Use of MRI instead of CT is typically limited to pediatric specialty centers with designated protocols because of issues related to cost, availability, limited experience with interpretation, and the potential need for sedation in younger children. (See 'Magnetic resonance imaging' below.)

  If a CT is performed, we use intravenous (IV) contrast alone and begin the evaluation with a focused examination, and expand the study to include the entire abdomen if an abnormality is seen on the uppermost image. When reviewing the images, coronal reformatted images increase the level of confidence in identification of the normal and abnormal appendix [9]. (See 'Contrast' below and 'Focused CT' below.)

ULTRASONOGRAPHY

Advantages and disadvantages — Ultrasonography (US) is available in most institutions, is relatively inexpensive, and avoids unnecessary radiation [10]. It has the added advantage of identifying ovarian pathology such as torsion or an ovarian cyst. In postmenarcheal females with right lower quadrant (RLQ) pain and no sign of appendicitis or equivocal findings, we routinely obtain a pelvic ultrasound.

Diagnostic performance — In pediatric patients, overall sensitivities of US for appendicitis and when performed by pediatric technicians and/or pediatric radiologists, including ultrasounds in which the appendix was not visualized, have varied from 74 to 100 percent; specificities have ranged from 88 to 99 percent [11-19]. Factors that increase the diagnostic accuracy of US in children include:

- Operator experience [12].

- Longer duration of abdominal pain [20].
- Incorporation of specific thresholds for white blood cell count (≤9000/microL) and proportion of polymorphonuclear cells (≤65 percent) [21] or white blood cell count alone (<11,000/microL) can increase the negative predictive value [22].
- Radiologists using a standardized template for interpreting RLQ ultrasound [23,24].

Diagnostic performance for US also varies by whether the appendix is visualized and patient body habitus:

- **Appendix visualized** – When the appendix is visualized, the diagnostic accuracy of US is comparable with CT [25]. As an example, in a multicenter study of 965 children undergoing abdominal ultrasound for possible appendicitis, sensitivity and specificity were 98 and 92 percent, respectively, in the 469 patients in whom the appendix was clearly seen [12].
- **Appendix not visualized** – The diagnosis of appendicitis **cannot** be reliably excluded by US unless a normal appendix is seen. Reported appendix visualization during pediatric US varies from 22 to 98 percent of examinations [13,14,26]. Factors that affect this variability primarily include the experience and technique of the sonographer.

  In these patients, the likelihood of appendicitis is not trivial, and clinical findings should be used to determine further care. For example, in one retrospective observational study of almost 490 children with suspected appendicitis with no appendix visualized on ultrasound, 7 percent were diagnosed with appendicitis [27]. In females with a negative or equivocal RLQ ultrasound, a pelvic ultrasound should also be performed to identify any ovarian pathology, such as torsion or an ovarian cyst.

  On the other hand, nonvisualization of the appendix with secondary signs indicative of appendicitis (eg, RLQ free fluid, fat stranding, or adjacent bowel wall thickening) still provides diagnostic support; absence of these secondary signs also has value for excluding appendicitis [28,29]. For example, in 212 children with suspected appendicitis undergoing US, the positive predictive value of these secondary signs for appendicitis was 85 percent (prevalence of appendicitis 34 percent); the negative predictive value of no secondary signs in patients whose appendix was not visualized was 100 percent [29].
- **High body mass index (BMI)** – In children with a high BMI, visualization of the appendix may be difficult and make inaccurate or equivocal ultrasound results more likely [30-32]. However, US is still an appropriate first study in these patients; we do not change our approach to imaging based upon the patient's body habitus. If clinical findings are concerning for appendicitis and the ultrasound is negative or equivocal, then surgical

consultation is the appropriate next step (algorithm 1). (See 'Pitfalls and limitations of US' below.)

Techniques — The following techniques may improve visualization of the appendix and permit more accurate diagnosis of appendicitis:

- **Posterior compression** – The addition of posterior manual compression to graded compression can help to identify the appendix. This was demonstrated in a report of 570 consecutive patients referred for suspected appendicitis, 28 percent of whom were less than 16 years of age [33]. Visualization of the appendix increased from 85 to 95 percent with posterior manual compression.

- **Positional scanning** – Scanning in the flank and pelvis, in addition to the RLQ, may be useful. Among 199 children with appendicitis on pathology, scanning of the retrocecal area using a posterolateral approach, followed by scanning of the pelvis through a full urinary bladder and scanning of the RLQ resulted in identification of an abnormal appendix in 68 percent of these patients [14]. The combination of noncompressive and compressive techniques increased the identification rate to 96 percent.

- **Point of care ultrasound (POCUS)** – Evidence also suggests that emergency physicians with proper training and experience in performing POCUS for appendicitis can achieve reasonable diagnostic accuracy in children. For example, in a meta-analysis of 21 studies, the pooled sensitivity and specificity for pediatric examinations was 89 to 96 percent and 92 to 97 percent, respectively [34]. However, the accuracy of POCUS for appendicitis in children is operator dependent and requires a rigorous scanning protocol that results in consistent visualization of the appendix. POCUS also requires an ongoing quality review and documentation process that includes saving the images in the patient record for review and comparison with subsequent examinations.

Sonographic findings — Ultrasound findings that support the diagnosis of appendicitis include the following (table 3):

- Noncompressible tubular structure in the RLQ (image 1)
- Wall thickness of the appendix greater than 2 mm (image 2 and image 3 and image 4)
- Overall diameter greater than 6 mm (image 1 and image 3)
- Hyperemia (image 1)
- Free fluid in the RLQ (image 3 and image 4)
- Thickening of the mesentery
- Localized tenderness with graded compression
- Presence of a calcified appendicolith (fecalith) (image 1)

A small number of children with a normal appendix visualized on ultrasound may have early, or tip, appendicitis. How often this occurs is unknown. Consequently, clinical correlation, observation, and serial examination for 12 to 24 hours with repeated US or performance of enhanced CT or magnetic resonance imaging (MRI) may be required to exclude the diagnosis of appendicitis, even with a normal US examination.

Diagnoses that can mimic appendicitis on ultrasound include lymphoma, Crohn disease, and cystic fibrosis [35]. In cystic fibrosis, the appendix may be markedly dilated with thickened secretions, leading to an inaccurate diagnosis of appendicitis.

In addition, we have seen some false-positive ultrasound reports in which the diagnosis of appendicitis was based upon increased appendiceal wall thickness alone. We advise caution in utilizing ultrasound reports as the sole criterion for diagnosis of appendicitis without other supportive clinical findings, specifically leukocytosis and a preponderance of PMNs (shift) on differential [21].

However, the value of standardized ultrasound reporting templates when adopted as part of the implementation of a clinical pathway for pediatric acute appendicitis has been demonstrated by many studies using a multidisciplinary approach and quality improvement methods; utilization of such standardized reporting systems can reduce the use of CT scans and their associated radiation exposure [23,24] and decrease annual imaging costs [36] while preserving diagnostic performance and important balance metrics, such as negative appendectomy rates (NARs) [19,37]. Adding posterior manual compression to graded compression [33] and scanning the flank and pelvis [14] may also improve the diagnostic accuracy of US for appendicitis.

In our practice, visualization of a normal appendix constitutes a normal ultrasound examination. When the appendix is not visualized in an otherwise unremarkable pelvic ultrasound examination, we report the study as showing no evidence of appendicitis. In one retrospective observational study of almost 490 children with suspected appendicitis but no appendix visualized on ultrasound, 7 percent were diagnosed with appendicitis [27]. Predictors for appendicitis in this study included RLQ inflammatory changes, elevated white blood cell count or C-reactive protein, and duration of abdominal pain for less than three days. In some settings, nonvisualization of the appendix with secondary signs suggestive of appendicitis is an infrequently encountered ultrasound finding. In a review of 3750 ultrasound exams of which only 4.3 percent were deemed equivocal based on a six-point risk-stratified scoring system, the additional findings of loss of mural stratification, periappendiceal fat inflammation, and presence of an appendicolith were significant predictors of appendicitis in children with otherwise equivocal exams [28].

The need for further imaging is determined by the requesting clinician. If further imaging is desired, we typically perform contrast-enhanced CT. In other institutions, MRI without contrast may be substituted for CT. (See 'Magnetic resonance imaging' below.)

Pitfalls and limitations of US — There are a number of limitations for US in the diagnosis of acute appendicitis:

- Fat absorbs and diffuses the ultrasound beam making it more difficult to scan overweight children.
- It can be difficult to identify a normal appendix or one that is only focally inflamed ("tip" appendicitis). Therefore, a negative ultrasound examination in the presence of persistent symptoms is not sufficient to reliably exclude appendicitis.
- Pain and/or anxiety may make sonographic imaging of the abdomen difficult or impossible in some children.
- Many institutions have limited or no access to staff trained to perform US in children during all hours of operation.

COMPUTED TOMOGRAPHY

Advantages and disadvantages — Enhanced computed tomography (CT) is a commonly used imaging modality for testing of children with possible appendicitis who have nondiagnostic findings on ultrasound, although magnetic resonance imaging (MRI) is used in some institutions instead of CT, primarily in patients older than six years of age who can cooperate with the examination. (See 'Magnetic resonance imaging' below.)

CT is typically more available and less operator-dependent than US but has the disadvantage of significant exposure to radiation and risk of late-onset cancer (see "Radiation-related risks of imaging", section on 'Children and adolescents'). For this reason, ultrasonography (US) is the preferred initial diagnostic test in children with suspected appendicitis. In settings where US is not available, the child should undergo transfer to a pediatric facility for further evaluation with US and by a surgeon with pediatric expertise whenever possible.

CT is also useful in establishing alternative diagnoses for abdominal pain. As an example, in one observational study of 125 children examined with focused CT that was negative for possible appendicitis, 62 had alternative diagnoses made including ileitis or colitis suggestive of inflammatory bowel disease, mesenteric adenitis, and intact or ruptured ovarian cyst [38].

Diagnostic performance — In children, sensitivity for the diagnosis of acute appendicitis by CT is 94 to 100 percent, and specificity is 93 to 100 percent [13,17,20,38-40]. In one large, observational study of 1810 children with suspected appendicitis, CT had high sensitivity and specificity regardless of the duration of abdominal pain [20].

CT has the disadvantage of exposure to ionizing radiation [41-44]. In addition, some children have a paucity of mesenteric fat, which makes visualization of either a normal or an inflamed appendix more difficult, especially on an unenhanced CT [45]. For this reason, we prefer ultrasound to CT for initial imaging in children with abdominal pain and moderate risk of appendicitis.

Increased utilization of CT and improved accuracy of imaging for acute appendicitis have not contributed substantially to lower rates of negative appendectomy since the mid-1990s, and the perforation rate remains as high as 33 percent [46,47]. This finding has raised concerns regarding increased exposure to ionizing radiation, health care costs, and delay in surgical treatment [41,42,48,49]. Protocols that emphasize early surgical evaluation, selective imaging that emphasizes US, and careful serial examination for patients with equivocal radiographic and/or clinical findings can achieve lower rates for negative appendectomy and perforation [48,50-52]. (See 'Approach (moderate risk of appendicitis)' above and 'Clinical protocols' below.)

The utility of CT for diagnosis of appendicitis in children may also vary according to patient age and sex. As an example, in a multicenter observational study of 55,227 children undergoing appendectomy, children younger than five years of age who underwent CT with or without a prior ultrasound had a clinically significant reduction in the negative appendectomy rate (NAR) when compared with children who did not receive a CT (NAR 5 versus 22 percent, respectively, for males [OR 0.18], NAR 2 versus 18 percent, respectively, for females [OR 0.11]) [53]. Among males five years of age and older who underwent appendectomy, the NAR was 1 percent and was not significantly different for those males who had advanced diagnostic imaging (US, CT, or both). Diagnostic imaging also did not greatly impact the NAR in females, although females older than 10 years of age had a higher NAR than either males or females 5 to 10 years old. Thus, CT was associated with the greatest reduction in the NAR among young children (<5 years of age). Limitations of this study include an inability to have clinical details for each case. Because the risk of radiation is highest in young children, US is the preferred initial test. A surgeon with pediatric expertise should make the decision to perform CT.

Techniques — Techniques to improve the accuracy and safety of CT include the use of intravenous (IV) contrast, limiting the examination to a focused CT of the pelvic contents, and adjusting scanning parameters to achieve the lowest radiation dose possible while maintaining diagnostic accuracy. Enteral contrast (rectal or oral) does not appear to improve diagnostic imaging over the use of IV contrast alone. (See 'Contrast' below.)

Contrast — We recommend that children with suspected appendicitis and nondiagnostic findings on ultrasound who proceed directly to CT undergo contrast-enhanced CT with IV contrast rather than no contrast. In addition, we suggest that children with suspected appendicitis undergo contrast-enhanced CT with IV contrast alone rather than IV contrast combined with enteral (oral or rectal) contrast.

IV contrast is helpful in identifying the appendix and adjacent structures, particularly in children under the age of 10 years who generally have limited mesenteric fat. For example, in 306 children with suspected appendicitis who underwent both unenhanced helical CT of the lower abdomen and IV contrast-enhanced CT of the entire abdomen, contrast-enhanced CT had a significantly higher pooled sensitivity for appendicitis than unenhanced CT (90 versus 66 percent, respectively) with similar specificity (94 versus 96 percent, respectively) [54]. (See 'Diagnostic performance' above.)

In addition, if a child with suspected appendicitis has equivocal or negative findings on an unenhanced CT, then frequently the study is repeated with contrast, thus increasing radiation exposure.

Contrast has also been given enterally (rectal or oral) to opacify and distend the cecum in an attempt to improve visualization of the inflamed appendiceal wall or mesentery [13,40,55]. However, observational studies suggest that rectal or oral contrast does not further improve test performance over IV contrast CT alone [56-58]. (See 'Diagnostic performance' above.)

Furthermore, enteral contrast administration presents several challenges. Rectal contrast administration is uncomfortable, difficult to administer in patients with diarrhea, and contraindicated in patients with intestinal perforation. Oral contrast delays scanning for approximately two hours, does not appear in the terminal ileum in up to 30 percent of patients at the time of CT scan, and may require nasogastric tube placement for proper administration [57].

IV contrast can cause hypersensitivity reactions, chemotoxicity, and kidney failure. However, these reactions are rare in children. The risk of contrast-induced immediate hypersensitivity can be reduced by using low osmolal contrast material agents (eg, iodixanol [Visipaque]) and in children with asthma, ensuring control of symptoms before the procedure. (See "Patient evaluation prior to oral or iodinated intravenous contrast for computed tomography", section on 'Patients with past reactions to contrast'.)

Focused CT — A CT scan limited to the lower abdomen may be sufficient to diagnose appendicitis, while exposing the child to less radiation. Some experts advocate scanning from the bottom of the third lumbar vertebral body to the pubic ramus. The scan can be expanded to include the upper abdomen if an abnormality is found on the initial uppermost image [59].

Support for this approach was demonstrated in a retrospective review of 93 abdominal CT scans obtained with oral and IV contrast in children with suspected appendicitis [60]. All of the abnormal findings leading to a diagnosis of appendicitis were located below the lower pole of the right kidney (RLP). In addition, there was no difference between the sensitivity and specificity for CT of the entire abdomen compared with CT below the RLP.

CT scanning parameters — CT scanning parameters, such as the tube current setting (in milliamperes) and pitch (table speed), should be adjusted based upon patient weight or girth to reduce radiation dose [44,61-64]. Weight-based reductions in tube current have been recommended [65]. Radiation dose can also be significantly reduced by increasing pitch. In addition, iterative reconstruction techniques have been shown to reduce radiation dose by 45 to 46 percent compared with traditional weight-based protocols while maintaining diagnostic accuracy [66].

Awareness of these recommendations may not be widespread, however. One report described the scanning parameters used for body CT examinations that had been obtained at referring hospitals and were then sent to a children's hospital for further review [67]. Mean tube current settings exceeded weight-based recommendations in all age groups, and 53 percent of studies were performed without an adjustment in pitch.

Important information on opportunities to reduce radiation dose during CT imaging in children can be found on the "Image Gently" website [68].

CT findings — The diagnosis of appendicitis is unlikely if the appendix is not identified as a separate structure on CT, and there are no additional signs of inflammation in surrounding structures. When multiplanar reformations are performed, the appendix is frequently best visualized in the coronal plane [58].

Findings on CT that support the diagnosis of appendicitis include (image 5 and table 4):

- Wall thickness greater than 2 mm
- Appendicolith (fecalith) (image 6 and image 7)
- Enlargement of the appendix (image 8)
- Concentric thickening of the appendiceal wall (target sign)
- Phlegmon
- Abscess (image 8)
- Free fluid
- Thickening of the mesentery, fat stranding

Other pathological processes that involve the appendix and can look like acute appendicitis on imaging studies include the following:

- Crohn disease and lymphoma may be indistinguishable from appendicitis on CT.
- Patients with cystic fibrosis may have a markedly enlarged appendix filled with mucus or stool without acute appendicitis.

Pitfalls and limitations of CT — There are several limitations to the use of CT for the diagnosis of appendicitis [55]:

- Scanning performed in institutions not familiar with pediatric protocols may result in excessive radiation.
- A normal appendix is more difficult to visualize in children with less intraperitoneal fat.
- A fluid-filled loop of small bowel may be misinterpreted as an inflamed appendix.
- If used, oral (intestinal contrast) can obscure the presence of an appendicolith.
- A Meckel diverticulum can be misinterpreted as an enlarged appendix.

MAGNETIC RESONANCE IMAGING

Advantages and disadvantages — The advantages of magnetic resonance imaging (MRI) include no ionizing radiation and no need for contrast, which are balanced by disadvantages such as limited availability of the scanner, need for sedation in uncooperative patients, expertise necessary to properly interpret the study, and higher cost than ultrasonography (US) or computed tomography (CT) [69,70]. Because MRI scanners are in high demand and access is limited in most hospitals, US as the initial imaging for children with suspected appendicitis is a more common approach and may be more cost-effective [70].

Diagnostic performance — In settings with adequate experience in interpreting MRI and the resources to rapidly obtain the study, noncontrast MRI has high diagnostic accuracy [7,69,71-74]. For example, in a prospective cohort study of over 600 children with suspected appendicitis who were managed by a US-rapid MRI clinical pathway (prevalence of appendicitis 24 percent), MRI after a nondiagnostic US (117 patients) had a sensitivity of 100 percent (95% CI 76-100 percent), specificity of 96 percent (95% CI 91-99 percent), and a negative predictive value of 100 percent (95% CI 97-100 percent) [7]. Three patients had a nondiagnostic MRI, none had appendicitis. Only one patient underwent CT after a nondiagnostic MRI and did not have appendicitis. In older meta-analyses that evaluated diagnostic accuracy of MRI for appendicitis in children, the pooled sensitivity and specificity were similar [71-73].

Techniques — Reported techniques include MRI without contrast using three to five axial and coronal T2 and coronal inversion recovery sequences and contrast-enhanced MRI [70,75,76].

Study duration depends upon the specific MRI protocol but was <20 minutes in a survey of pediatric hospitals in the United States and Canada who use rapid MRI for children with suspected appendicitis; access to an MRI scanner was typically 0.5 to 2 hours [70,77].

MRI findings — MRI findings that support the diagnosis of appendicitis are the same as those listed for CT (image 9 and image 10 and image 11 and table 4).

Pitfalls and limitations — Limitations for MRI may include:

- Availability of the magnet
- Need for patient cooperation if breath-holding sequences are used
- Greater need for sedation than US or CT
- Increased cost relative to US or CT
- Limited numbers of facilities equipped to image and interpret these studies in children

PLAIN RADIOGRAPHS

Plain radiographs of the abdomen are only indicated in children with suspected appendicitis and clinical signs of bowel obstruction (eg, bilious vomiting, severe abdominal pain, abdominal distension, and/or peritonitis [rigid abdomen, often with fever and shock]) [78]. Patients with these findings require resuscitation and urgent surgical consultation; plain radiographs may be obtained as part of the diagnostic imaging plan.

Otherwise, plain films are of limited value and should not be routinely performed. Plain films may occasionally show secondary signs in patients with acute appendicitis, such as a fecalith, or suggest an alternative diagnosis, such as basilar pneumonia (table 5).

CLINICAL PROTOCOLS

Imaging protocols for the diagnosis of appendicitis in children result in a significant decrease in radiation exposure without sacrificing diagnostic accuracy or clinical outcomes. We therefore endorse developing imaging protocols to streamline decision-making, improve safety, and decrease costs for all institutions managing children with suspected appendicitis. We prefer ultrasonography (US) for initial imaging of children with a moderate risk of appendicitis. (See 'Approach (moderate risk of appendicitis)' above.)

For facilities without US capabilities, conversation with pediatric colleagues should precede any decision about imaging.

US, computed tomography (CT), and magnetic resonance imaging (MRI) are all valuable modalities for imaging in children with suspected appendicitis. The choice of study in any given clinical situation depends upon patient characteristics, such as obesity and sex, and institutional resources and the expertise of the staff [59]. Of note, clinicians may be reluctant to use a protocol that includes modalities that are frequently unavailable or cannot be interpreted with confidence.

Observational studies that have evaluated outcomes before and after implementation of imaging protocols show decreased CT utilization of approximately 50 to 60 percent when imaging protocols prioritize US [79-81]. These protocols emphasize:

- Use of clinical scoring systems
- Examination by a surgeon with pediatric expertise to guide patient management decisions
- US as the initial imaging modality
- When feasible, MRI as the preferred imaging modality for children with equivocal ultrasound findings

Sensitivity and specificity for the diagnosis of appendicitis was high in two of these studies (sensitivity 98.6 to 99 percent, specificity 91 to 94 percent) without an increase in negative appendectomies [79,81]. In one study, missed appendicitis after protocol implementation was 0.5 percent [79]. When MRI was used instead of CT, sensitivity and specificity were also high (100 percent and 99 percent, respectively) with a negative appendectomy rate (NAR) of 1.5 percent [50].

However, even in settings where multidisciplinary protocols have been developed, achieving high rates of compliance can be difficult. For example, in two of the above studies, adherence to the protocol ranged from approximately 46 to 57 percent [79,81].

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Appendicitis in children".)

INFORMATION FOR PATIENTS

UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5th to 6th grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more detailed. These articles are written at the 10th to 12th grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Basics topics (see "Patient education: Appendicitis in adults (The Basics)" and "Patient education: Appendicitis in children (The Basics)")

SUMMARY AND RECOMMENDATIONS

- **Who to image** – The decision to perform imaging in the diagnostic evaluation of children with abdominal pain is determined by the estimated risk of appendicitis based upon clinical findings (algorithm 1) (see 'Who to image' above):
  - **Low risk** – Children with clinical findings that do not suggest appendicitis should **not** undergo imaging.
  - **Moderate risk** – For children with a moderate risk of appendicitis (eg, Pediatric Appendicitis score 3 to 6 (table 1) or similar constellation of findings with or without use of another formal clinical score), we prefer ultrasonography (US) as the initial imaging study rather than magnetic resonance imaging (MRI) or computed tomography (CT). Further management depends upon US findings. (See 'Approach (moderate risk of appendicitis)' above.)

    In settings where pediatric resources to perform and interpret imaging are **not** available, transfer of children with possible appendicitis to a center with pediatric radiology and pediatric general surgery capabilities should occur whenever possible. (See 'Who to image' above and "Acute appendicitis in children: Clinical manifestations and diagnosis", section on 'Imaging'.)
  - **High risk** – We prefer that children with a high likelihood of appendicitis based upon clinical findings undergo evaluation by a surgeon with pediatric expertise prior to diagnostic imaging. If imaging is performed prior to surgical evaluation, we advise an US rather than MRI or CT.
- **US performance** – Ultrasound findings that support the diagnosis of appendicitis are summarized in the table (table 3 and image 1 and image 2 and image 3 and image 4). When the appendix is visualized, the diagnostic accuracy of US may be similar to CT. (See 'Sonographic findings' above and 'Diagnostic performance' above.)

  If the appendix is not visualized or the findings on US are otherwise not diagnostic, options include (see 'Approach (moderate risk of appendicitis)' above):
  - Observation with serial physical examinations and repeated imaging (US, MRI, or contrast-enhanced CT) performed at a later time if a clinical diagnosis of appendicitis cannot be made. In patients whose initial ultrasound is not diagnostic for appendicitis, repeat physical examination and a second ultrasound in patients who have persistent findings of appendicitis has good diagnostic accuracy and can

markedly reduce the number of children undergoing MRI or CT. (See 'Approach (moderate risk of appendicitis)' above.)

- The patient may directly proceed to contrast-enhanced MRI or CT if a more rapid diagnosis is desired.

- **Magnetic resonance imaging** – In patients with a moderate risk of appendicitis and a nondiagnostic ultrasound, MRI with or without contrast may provide similar diagnostic accuracy as CT without radiation exposure or excessive time delay and may be preferred in settings with adequate experience in interpreting MRI for the presence of appendicitis and with the resources to rapidly obtain and interpret the study. (See 'Magnetic resonance imaging' above.)

  MRI findings that support the diagnosis of appendicitis are provided in the table (table 4 and image 9 and image 10 and image 11).

- **Computed tomography** – CT is typically more available and less operator-dependent than US but has the disadvantage of exposure to radiation. If CT is performed, we recommend that children undergo contrast-enhanced CT with intravenous (IV) contrast rather than no contrast. In addition, we suggest that these children undergo contrast-enhanced CT with IV contrast alone rather than IV contrast combined with enteral (oral or rectal) contrast. (See 'Contrast' above.)

  When using CT in children with possible appendicitis, radiation doses should be reduced as much as possible without compromising the accuracy of the study. (See 'Focused CT' above and 'CT scanning parameters' above.)

  CT findings that support the diagnosis of appendicitis are provided in the table (table 4 and image 5 and image 6 and image 7 and image 8).

- **Clinical protocols** – Institutions should develop imaging protocols that they can utilize effectively. Such protocols have been associated with increased diagnosis of appendicitis at initial presentation, reduced radiation exposure, decreased negative appendectomy rate (NAR), and no increase in perforation rate. (See 'Clinical protocols' above.)

ACKNOWLEDGMENT

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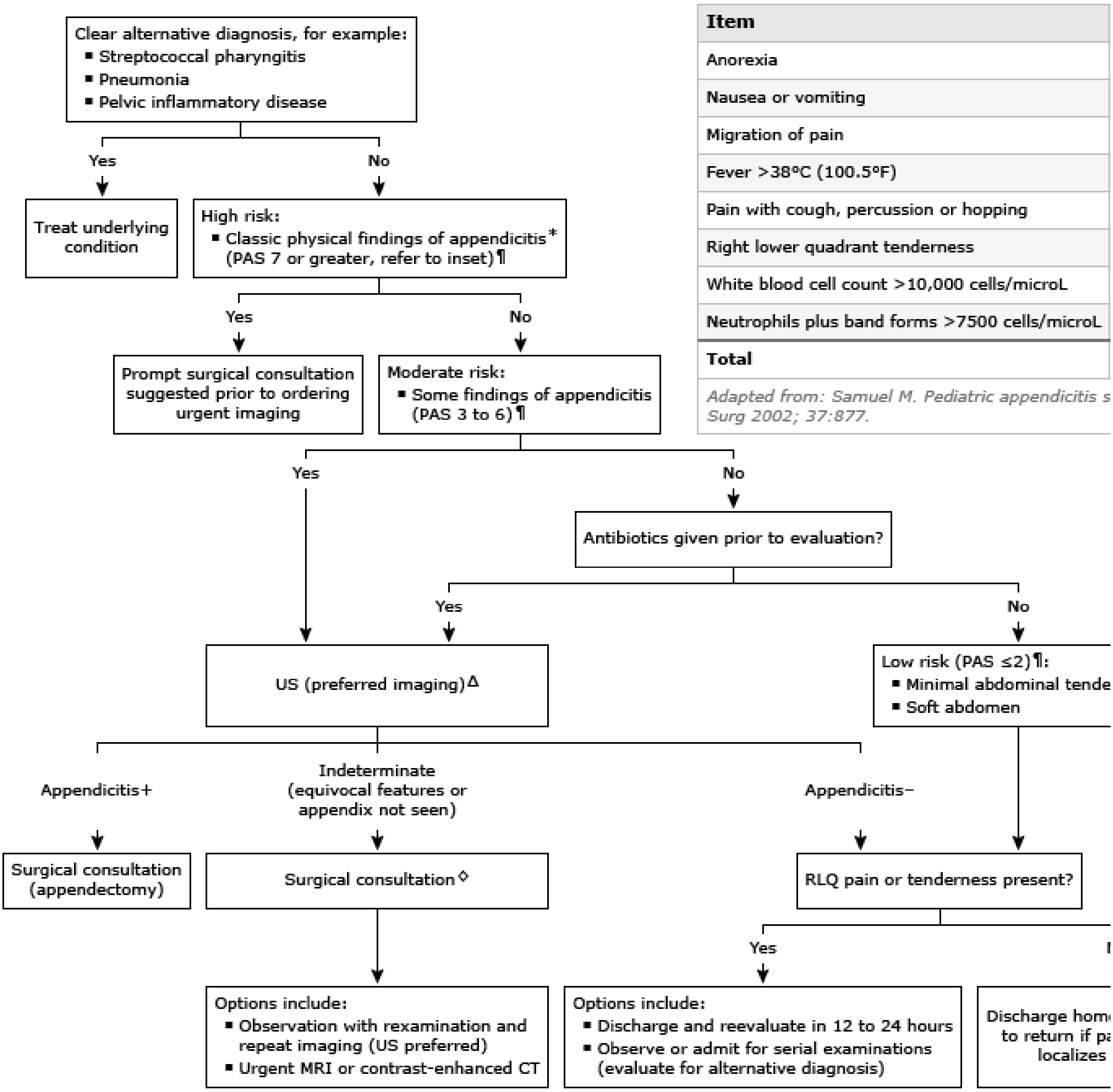
Topic 6478 Version 58.0

GRAPHICS

Approach to children with suspected appendicitis



The Pediatric Appendicitis Score

Item
Anorexia
Nausea or vomiting
Migration of pain
Fever >38°C (100.5°F)
Pain with cough, percussion or hopping
Right lower quadrant tenderness
White blood cell count >10,000 cells/microL
Neutrophils plus band forms >7500 cells/microL
Total

Adapted from: Samuel M. Pediatric appendicitis s Surg 2002; 37:877.

This algorithm provides an approach to children with suspected appendicitis to aid in diagnosis, including clinical findings that indicate the need for imaging and/or consultation with a surgeon with pediatric expertise as well as guidance for disposition and management as determined by initial evaluation. For additional detail, refer to UpToDate topics on the clinical manifestations, diagnosis, and management of appendicitis in children.

ANC: absolute neutrophil count; C: Centigrade; CRP: C-reative protein; F: Fahrenheit; PAS: Pediatric Appendicitis Score; RLQ: right lower quadrant; US: ultrasonography; WBC: white blood cell count.

* Classic signs of appendicitis consist of abdominal pain for less than 2 days that begins periumbilically and then begins to radiate and localize to the right lower quadrant. The pain is associated with

anorexia, vomiting, and low grade fever. RLQ tenderness is present on physical examination and the white blood cell count, absolute neutrophil count, and/or C-reactive protein are elevated.

¶ Applies to patients with a similar constellation of findings with or without use of another clinical prediction rule.

Δ For patients with a moderate risk of appendicitis based upon the Pediatric Appendicitis Score or a similar constellation of findings with or without the use of another clinical prediction rule, diagnostic imaging prior to surgical consultation is typically performed. We prefer US. If local resources are insufficient to adequately perform or interpret pediatric diagnostic imaging or if surgeons with pediatric expertise are not available, the patient should be transferred to a facility with pediatric radiologic and surgical capability and no imaging should be performed at the local institution. Refer to UpToDate content on appendicitis in children: diagnostic imaging.

◇ MRI may be obtained by experienced pediatric emergency medicine specialists prior to surgical consultation as part of an agreed upon multidisciplinary protocol/pathway if obtaining and interpreting the image is timely.

Graphic 96236 Version 4.0

The Pediatric Appendicitis Score

Item	Score (point)
Anorexia	1
Nausea or vomiting	1
Migration of pain	1
Fever >38°C (100.5°F)	1
Pain with cough, percussion or hopping	2
Right lower quadrant tenderness	2
White blood cell count >10,000 cells/microL	1
Neutrophils plus band forms >7500 cells/microL	1
Total	**10 points**

C: Centigrade; F: Fahrenheit.

Adapted from: Samuel M. Pediatric appendicitis score. J Pediatr Surg 2002; 37:877.

Graphic 62136 Version 3.0

Causes of acute abdominal pain in children by age

Neonate	1 month to 2 years	2 to 5 years	>5 years
▪ Adhesions* ▪ Necrotizing enterocolitis* ▪ Volvulus* ▪ Colic¶ ▪ Dietary protein allergy ▪ Testicular torsion ▪ Appendicitis (rare)*	▪ Adhesions* ▪ Foreign body ingestion* ▪ Hemolytic uremic syndrome* ▪ Hirschsprung disease* ▪ Incarcerated hernia* ▪ Intussusception* ▪ Trauma (including inflicted injury)* ▪ Gastroenteritis¶ ▪ Viral illness¶ ▪ Dietary protein allergy ▪ Hepatitis ▪ Inflammatory bowel disease ▪ Meckel's diverticulum ▪ Sickle cell syndrome vasoocclusive crisis ▪ Toxin ▪ Tumor ▪ Urinary tract infection ▪ Appendicitis (rare)*	▪ Adhesions* ▪ Appendicitis* ▪ Foreign body ingestion* ▪ Hemolytic uremic syndrome* ▪ Intussusception* ▪ Primary bacterial peritonitis* ▪ Trauma (including inflicted injury)* ▪ Gastroenteritis¶ ▪ Viral illness¶ ▪ Pharyngitis¶ ▪ Constipation¶ ▪ IgA vasculitis (previously Henoch Schönlein purpura) ▪ Hepatitis ▪ Inflammatory bowel disease ▪ Intraabdominal abscess ▪ Meckel's diverticulum ▪ Urinary tract infection ▪ Ovarian torsion ▪ Pancreatitis ▪ Pneumonia ▪ Sickle cell syndrome vasoocclusive crisis ▪ Toxin ▪ Tumor	▪ Adhesions* ▪ Appendicitis* ▪ Diabetic ketoacidosis* ▪ Hemolytic uremic syndrome* ▪ Myocarditis* ▪ Pericarditis* ▪ Perforated ulcer* ▪ Primary bacterial peritonitis* ▪ Trauma* ▪ Constipation¶ ▪ Gastroenteritis¶ ▪ Pharyngitis¶ ▪ Viral illness¶ ▪ Abdominal migraine ▪ Cholecystitis or cholelithiasis ▪ Familial Mediterranean fever ▪ Gastrointestinal dysmotility ▪ IgA vasculitis (previously Henoch Schönlein purpura) ▪ Hepatitis ▪ Inflammatory bowel disease ▪ Intraabdominal abscess ▪ Meckel's diverticulum ▪ Ovarian torsion ▪ Pancreatitis ▪ Pneumonia ▪ Acute porphyria (adolescents) ▪ Ruptured ovarian cyst ▪ Sickle cell syndrome vasoocclusive crisis

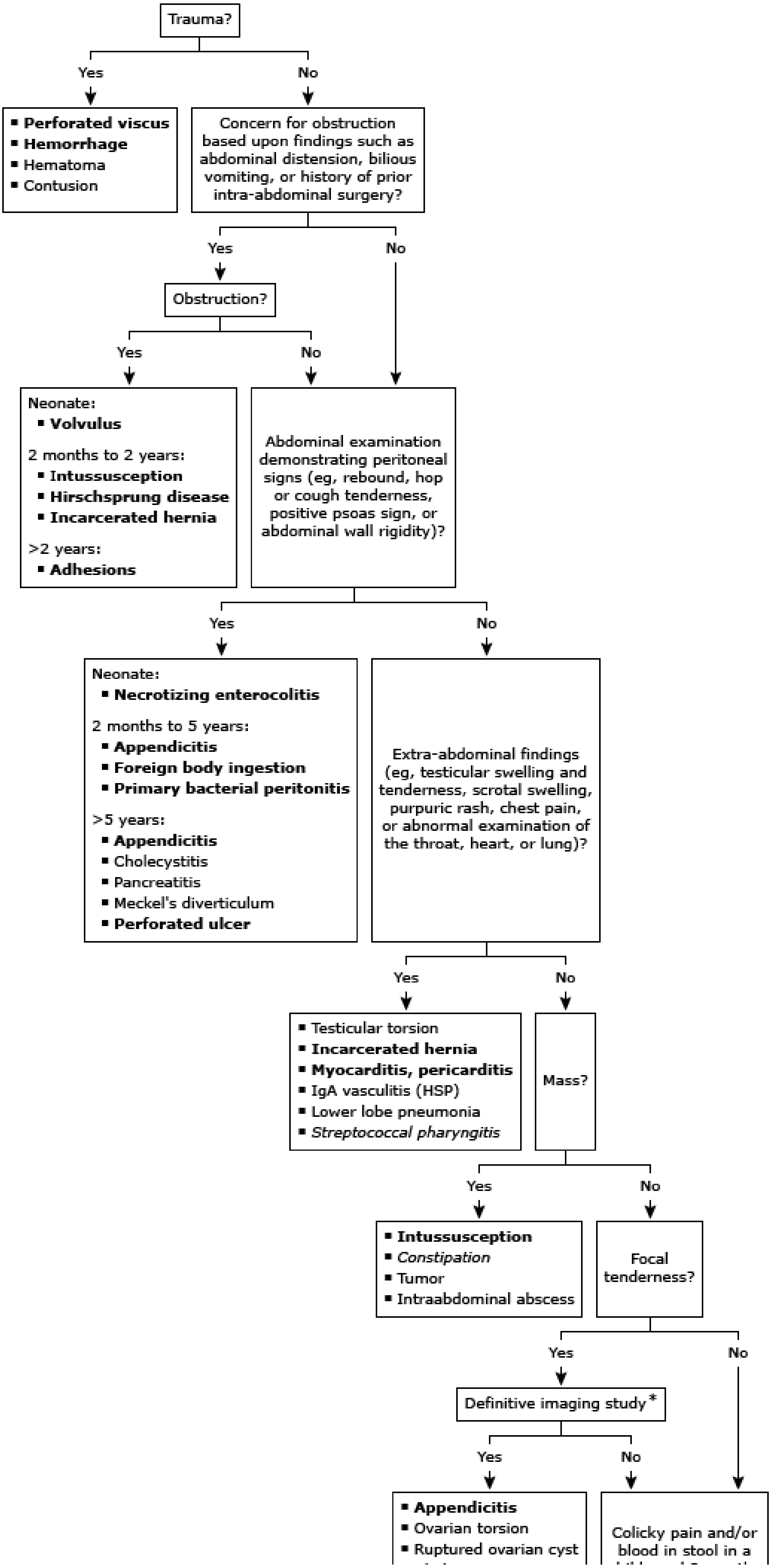
			- Testicular torsion - Urinary tract infection - Kidney stone - Toxin

* Life-threatening condition.

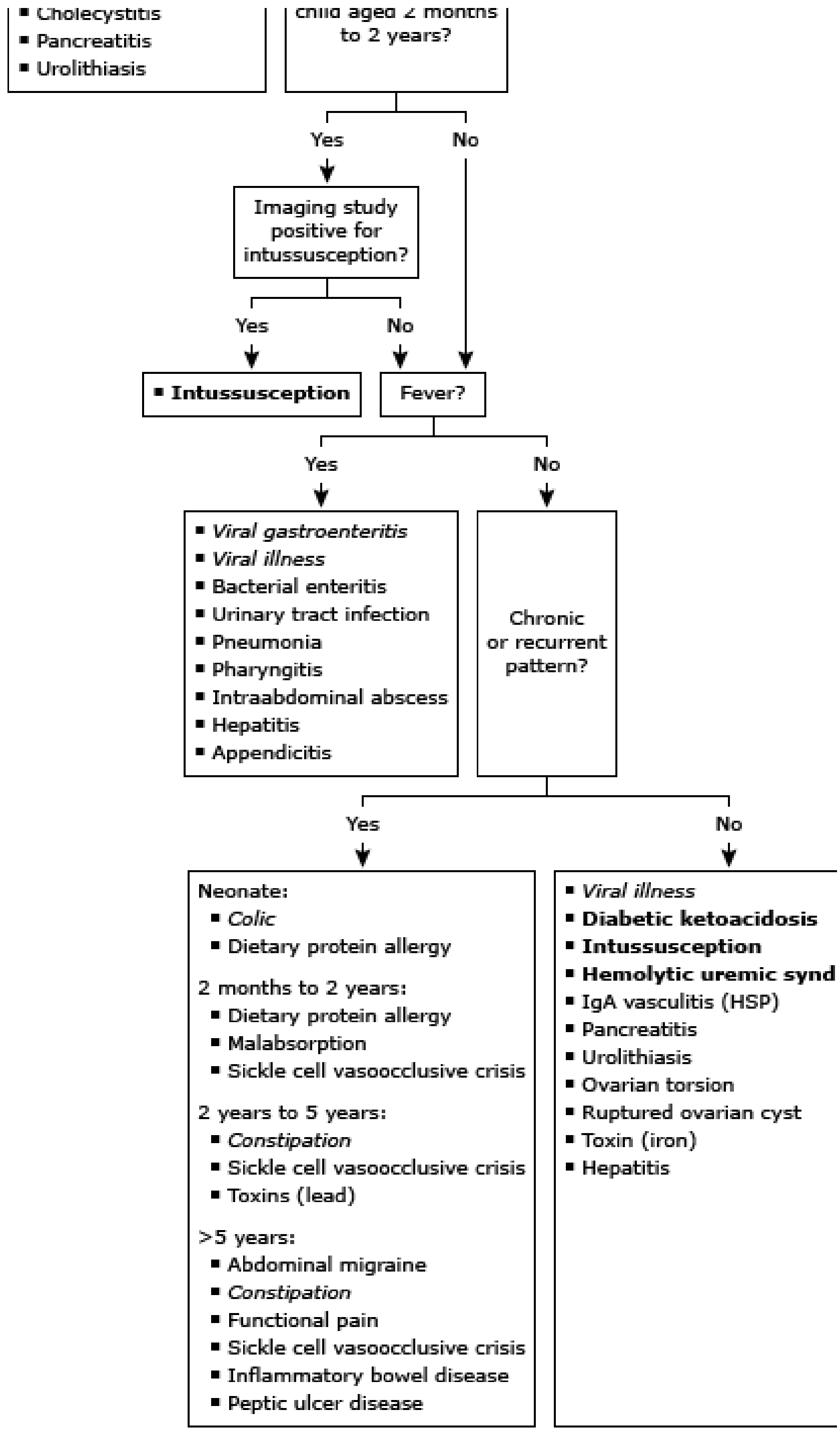
¶ Common condition.

Graphic 65488 Version 13.0

Emergency department evaluation of abdominal pain: Males and premenarchal females



Trauma?
Yes
No
Perforated viscus
Hemorrhage
Hematoma
Contusion
Concern for obstruction based upon findings such as abdominal distension, bilious vomiting, or history of prior intra-abdominal surgery?
Yes
No
Obstruction?
Yes
No
Neonate:
Volvulus
2 months to 2 years:
Intussusception
Hirschsprung disease
Incarcerated hernia
>2 years:
Adhesions
Abdominal examination demonstrating peritoneal signs (eg, rebound, hop or cough tenderness, positive psoas sign, or abdominal wall rigidity)?
Yes
No
Neonate:
Necrotizing enterocolitis
2 months to 5 years:
Appendicitis
Foreign body ingestion
Primary bacterial peritonitis
>5 years:
Appendicitis
Cholecystitis
Pancreatitis
Meckel's diverticulum
Perforated ulcer
Extra-abdominal findings (eg, testicular swelling and tenderness, scrotal swelling, purpuric rash, chest pain, or abnormal examination of the throat, heart, or lung)?
Yes
No
Testicular torsion
Incarcerated hernia
Myocarditis, pericarditis
IgA vasculitis (HSP)
Lower lobe pneumonia
Streptococcal pharyngitis
Mass?
Yes
No
Intussusception
Constipation
Tumor
Intraabdominal abscess
Focal tenderness?
Yes
No
Definitive imaging study*
Yes
No
Appendicitis
Ovarian torsion
Ruptured ovarian cyst
Colicky pain and/or blood in stool in a



Bold text: Life-threatening conditions.

Italic text: Common conditions.

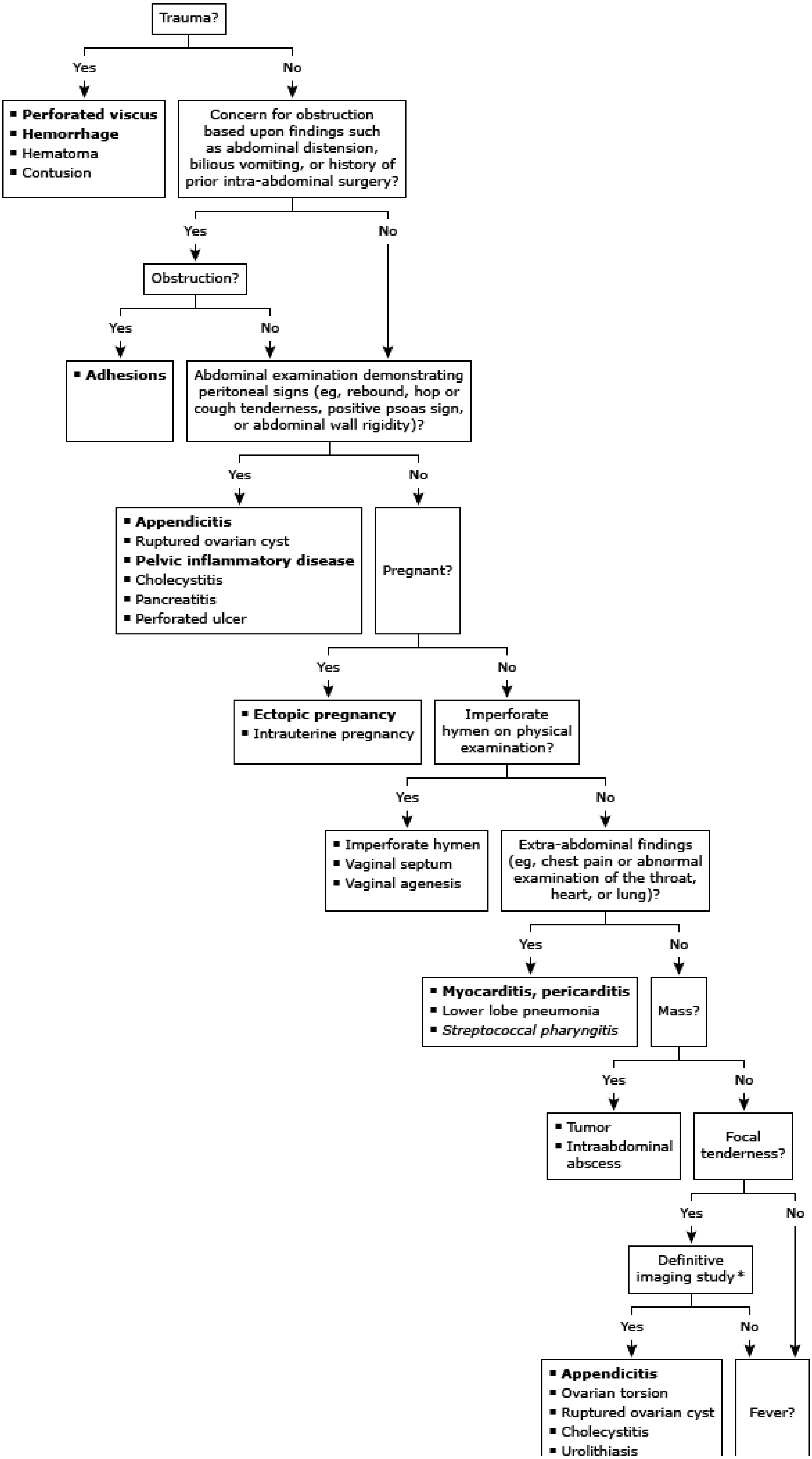
For more details regarding the diagnostic approach for specific conditions, refer to UpToDate topics on emergency evaluation of abdominal pain in children.

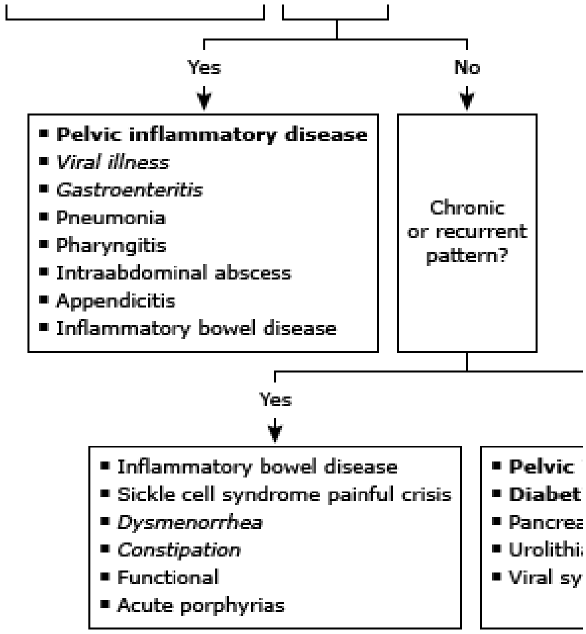
HSP: Henoch-Schönlein purpura

* The approach to imaging depends upon the suspected etiology. Refer to UpToDate pediatric content on imaging of the gall bladder, pancreas, kidneys, ovaries, and appendix.

Graphic 57204 Version 6.0

Emergency department evaluation of abdominal pain in postmenarchal females


Trauma?
Yes
No
Perforated viscus
Hemorrhage
Hematoma
Contusion
Concern for obstruction based upon findings such as abdominal distension, bilious vomiting, or history of prior intra-abdominal surgery?
Yes
No
Obstruction?
Yes
No
Adhesions
Abdominal examination demonstrating peritoneal signs (eg, rebound, hop or cough tenderness, positive psoas sign, or abdominal wall rigidity)?
Yes
No
Appendicitis
Ruptured ovarian cyst
Pelvic inflammatory disease
Cholecystitis
Pancreatitis
Perforated ulcer
Pregnant?
Yes
No
Ectopic pregnancy
Intrauterine pregnancy
Imperforate hymen on physical examination?
Yes
No
Imperforate hymen
Vaginal septum
Vaginal agenesis
Extra-abdominal findings (eg, chest pain or abnormal examination of the throat, heart, or lung)?
Yes
No
Myocarditis, pericarditis
Lower lobe pneumonia
Streptococcal pharyngitis
Mass?
Yes
No
Tumor
Intraabdominal abscess
Focal tenderness?
Yes
No
Definitive imaging study*
Yes
No
Appendicitis
Ovarian torsion
Ruptured ovarian cyst
Cholecystitis
Urolithiasis
Fever?



Bold text: Life-threatening conditions.

Italic text: Common conditions.

For more details regarding the diagnostic approach for specific conditions, refer to UpToDate topics on emergency evaluation of abdominal pain in children.

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* The approach to imaging depends upon the suspected etiology. Refer to UpToDate pediatric content on imaging of the gall bladder, kidneys, ovaries, and appendix.

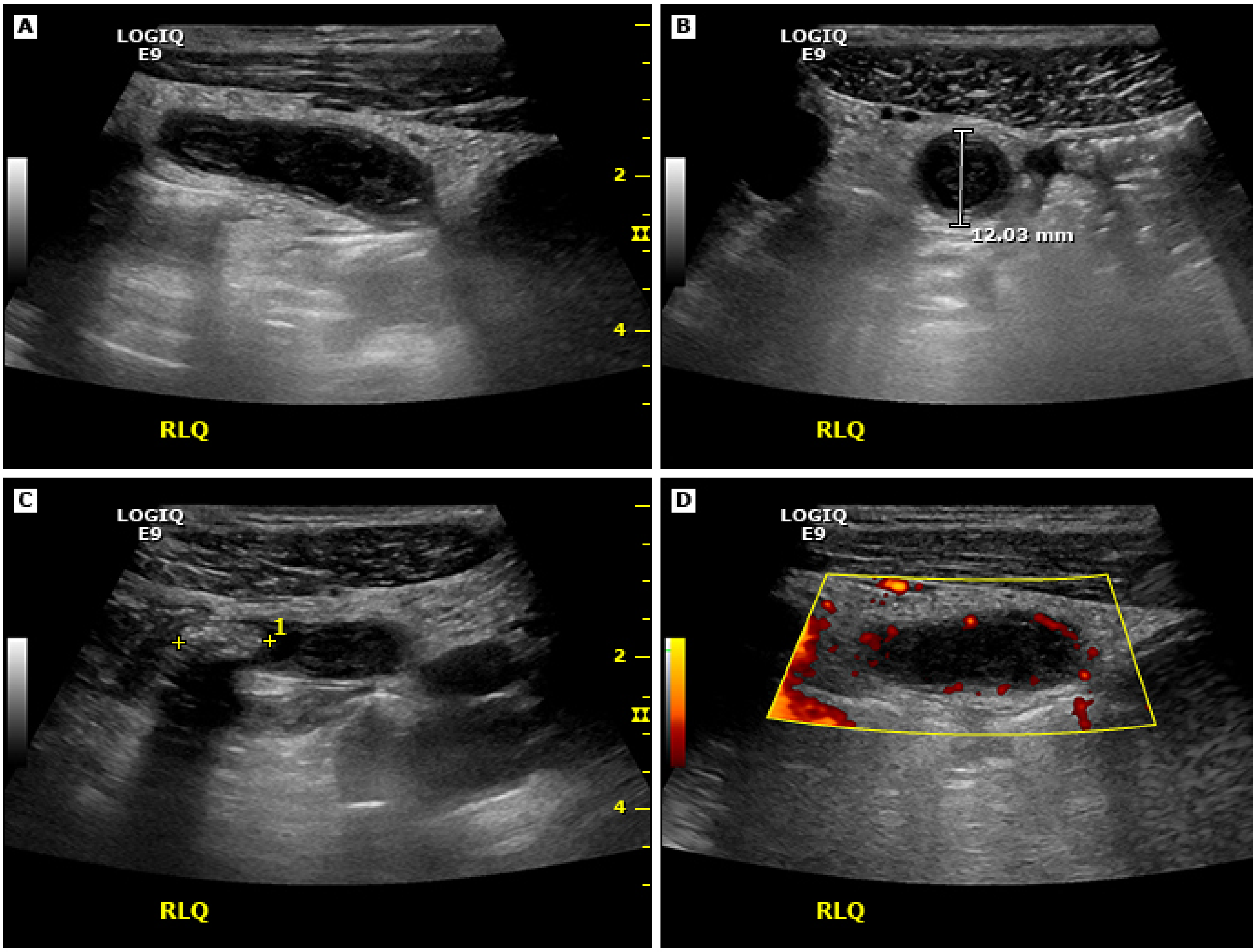
Graphic 69041 Version 10.0

Ultrasonographic signs of acute appendicitis

Non-compressible tubular structure in the right lower quadrant
Wall thickness >2 mm
Overall diameter >6 mm
Free fluid in the right lower quadrant
Thickening of the mesentery
Localized tenderness with graded compression
Presence of a calcified appendicolith

Graphic 61146 Version 2.0

Ultrasound findings of appendicitis



These ultrasound images are taken from a patient with early appendicitis at surgery. They demonstrate important diagnostic findings of acute appendicitis without evidence for perforation or abscess formation:

(A) A dilated tubular fluid-filled structure in the right lower quadrant with a blind-ending tip is identified, consistent with the appendix.

(B) The appendix is dilated, measuring up to 1.2 cm in the transverse dimension.

(C) There is a hyperechoic shadowing focus within the midportion of the appendix, consistent with an appendicolith.

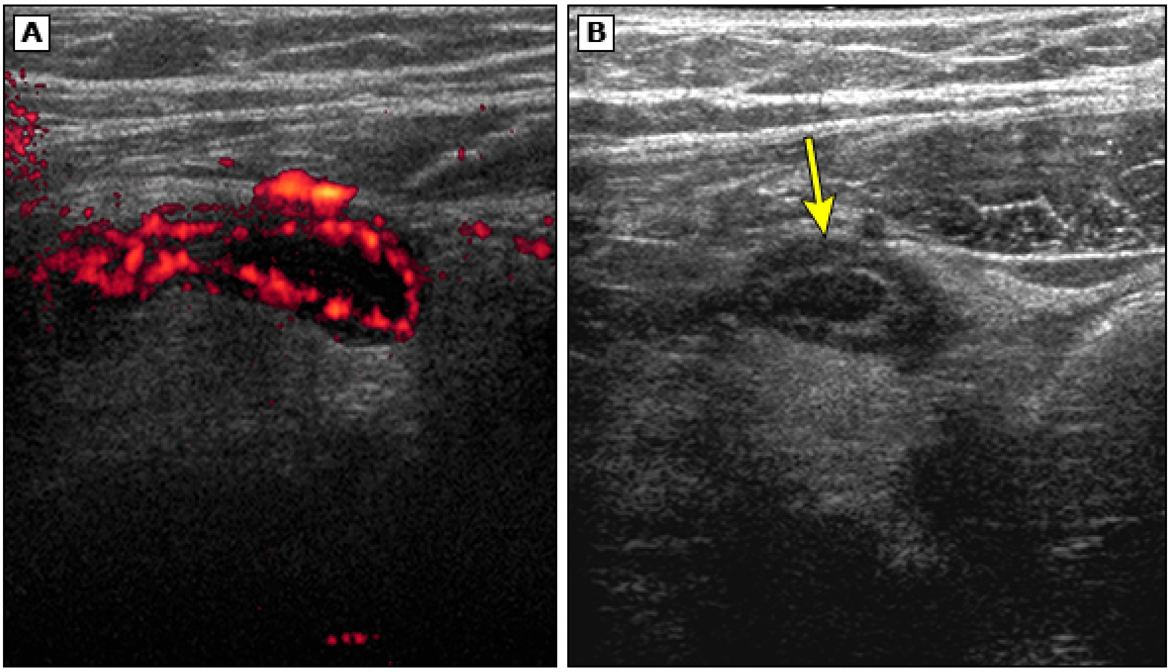
(D) There is increased echogenicity of the periappendiceal fat and hyperemia observed on color Doppler imaging.

On further ultrasound imaging (not shown), there is trace free fluid noted in the right lower quadrant, and no periappendiceal abscess is identified.

Courtesy of Mark I Neuman, MD, MPH.

Graphic 122058 Version 1.0

Ultrasound of a hyperemic appendix with a thickened wall

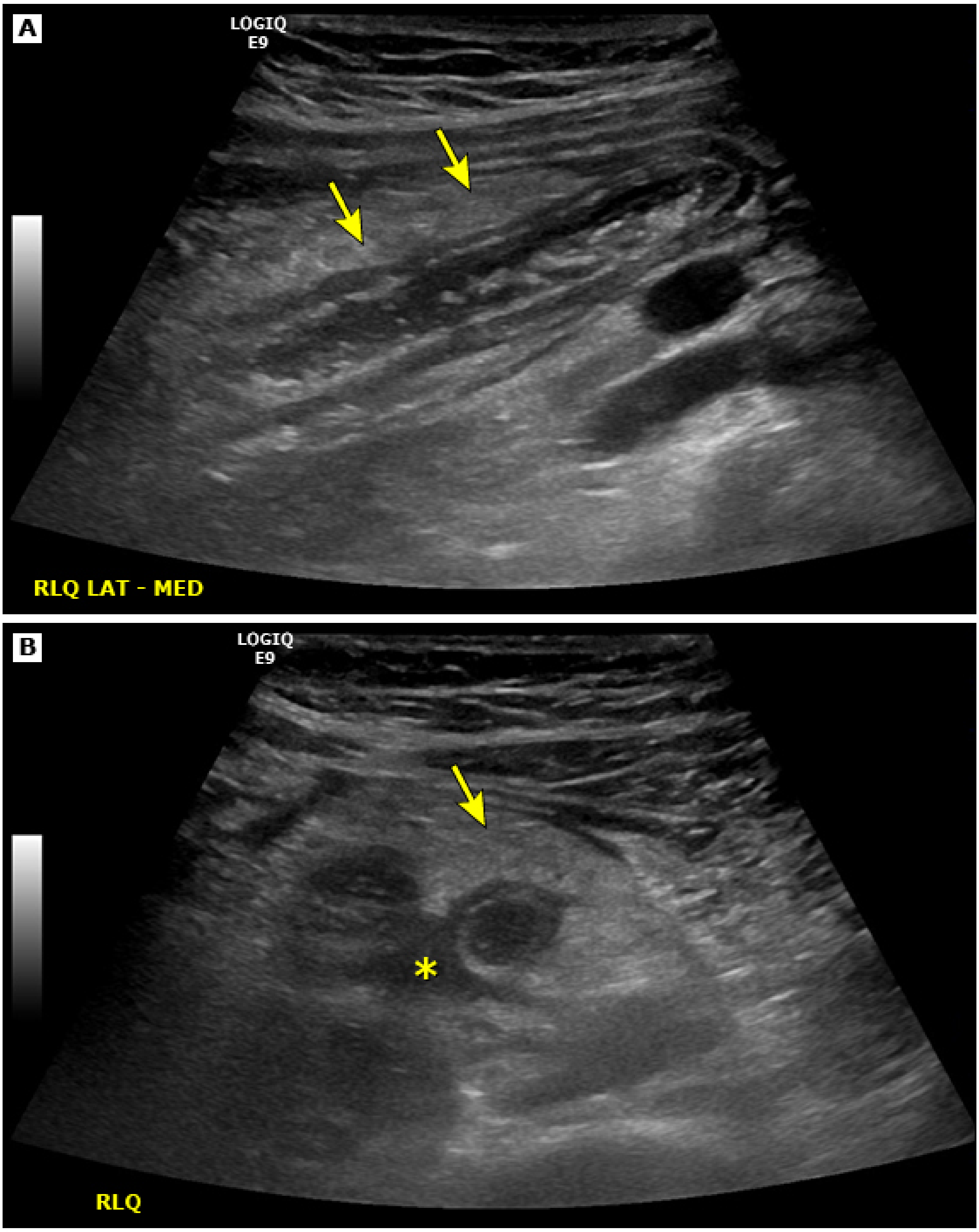


Acute appendicitis: 17-year-old female with right lower quadrant pain. Sagittal power Doppler ultrasound (US) image of the appendix (A) shows a markedly hyperemic appendix. Transverse US image of the appendix (B) shows a fluid-filled, appendix with thickened wall (4 mm, arrow). Note echogenic, surrounding fat consistent with peri-appendiceal inflammation.

Courtesy of George Taylor, MD.

Graphic 95531 Version 2.0

Right lower quadrant abdominal ultrasound showing appendicitis in an adolescent



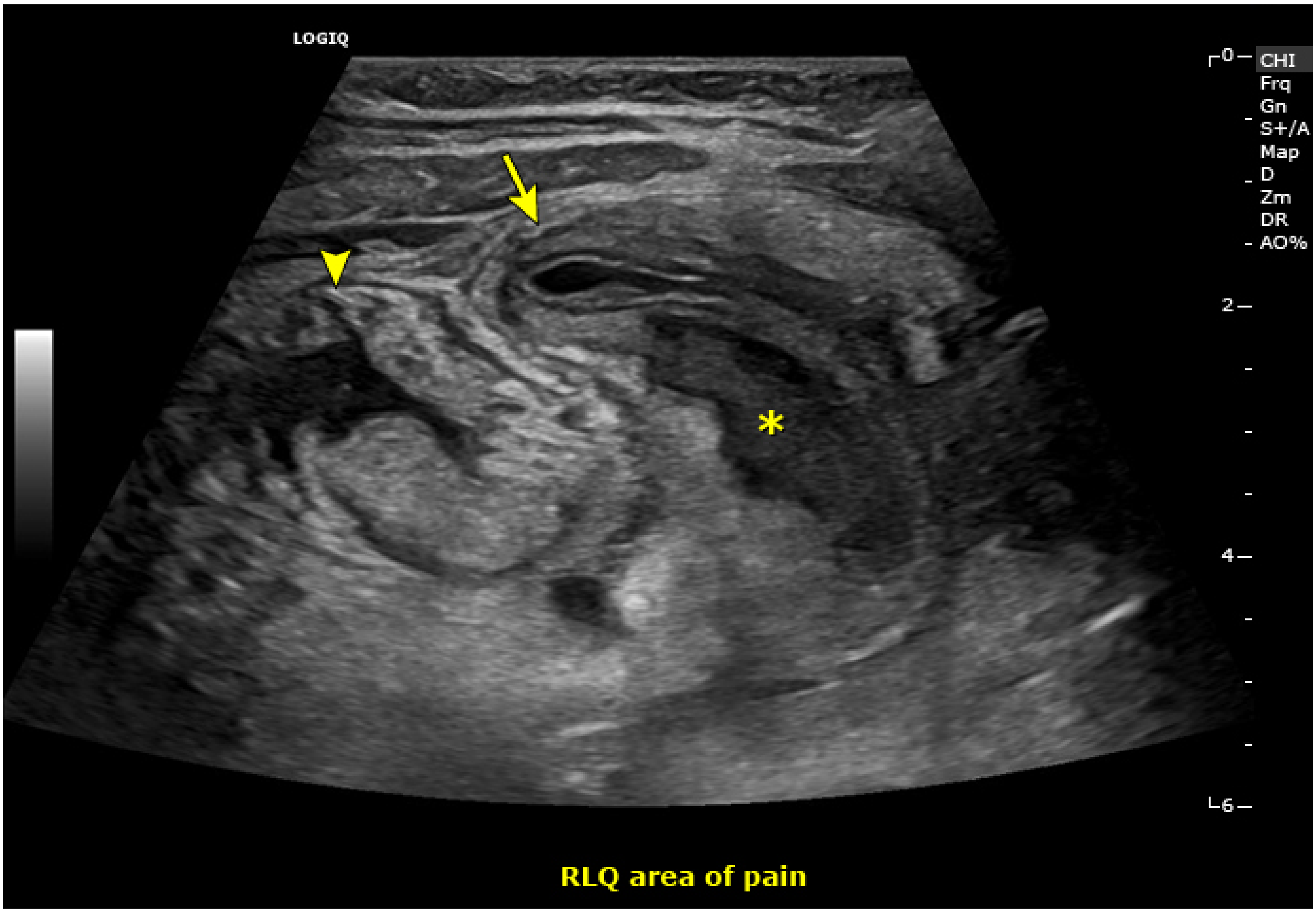
A 16-year-old male presented with RLQ abdominal pain, leukocytosis, and fever. Ultrasound of the right lower quadrants demonstrates a dilated appendix in sagittal (A) and transverse (B) planes with distension up to 11 mm in thickness, wall thickening >2 mm, surrounding echogenic fat (arrows), and adjacent fluid (*).

RLQ: right lower quadrant.

Courtesy of Wendy G Kim, MD.

Graphic 143914 Version 1.0

Right lower quadrant ultrasound in a 6-year-old male with perforated appendicitis

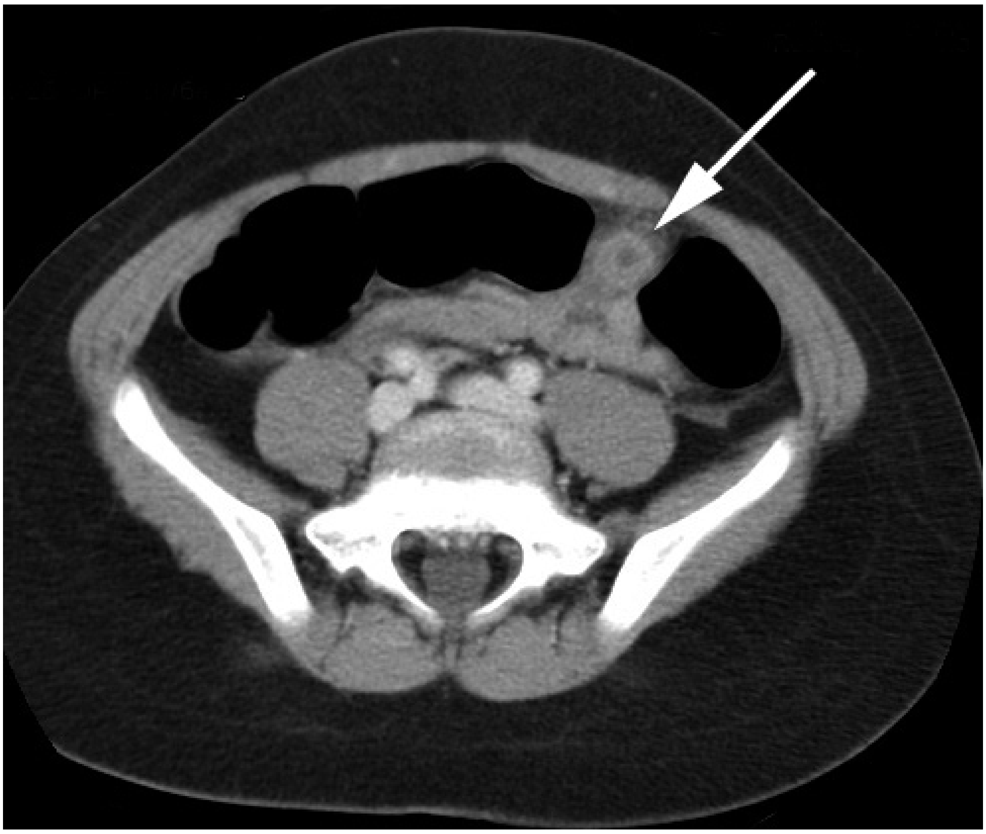


This 6-year-old male presented with right lower quadrant abdominal pain. Targeted ultrasound demonstrates a thickened appendix (arrow), with an ill-defined wall and complex periappendiceal fluid collection (*), and an adjacent thickened bowel loop (arrowhead). Findings are consistent with a perforated appendicitis.

Courtesy of Wendy G Kim, MD.

Graphic 143916 Version 1.0

Computed tomography of appendicitis in a child



CT of the pelvis following administration of intravenous contrast material in an 8-year-old boy with midline pelvic pain, fever, and leucocytosis shows an enlarged, fluid filled, abnormally enhancing appendix and associated mesenteric inflamation to the left of midline (arrow).

Courtesy of George A Taylor, MD.

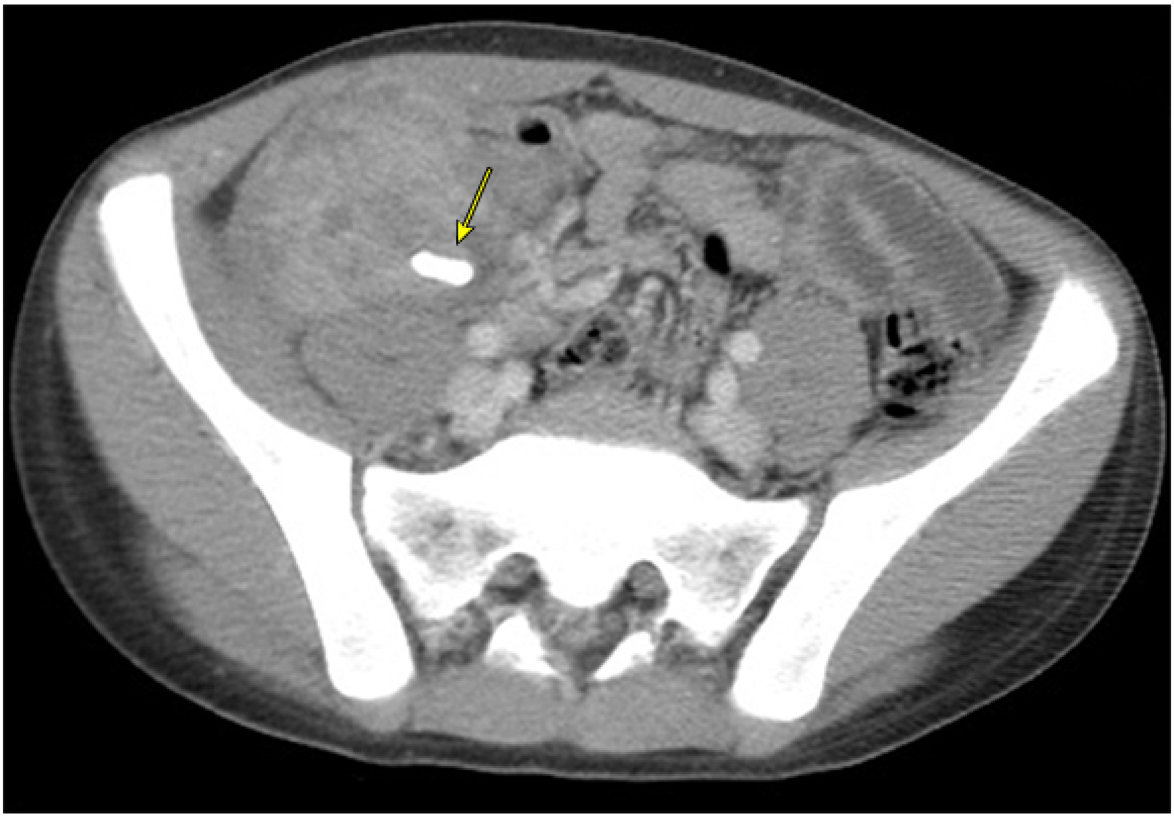
Graphic 70709 Version 2.0

Computed tomography and magnetic resonance imaging signs of acute appendicitis

Wall thickness >2 mm
Appendicolith
Enlargement of the appendix
Target sign (concentric thickening of the appendiceal wall)
Phlegmon
Abscess
Free fluid
Thickening of the mesentery, fat stranding (peri-appendiceal inflammation)

Graphic 58384 Version 3.0

Abdominal computed tomography showing a peri-appendiceal abscess and fecalith

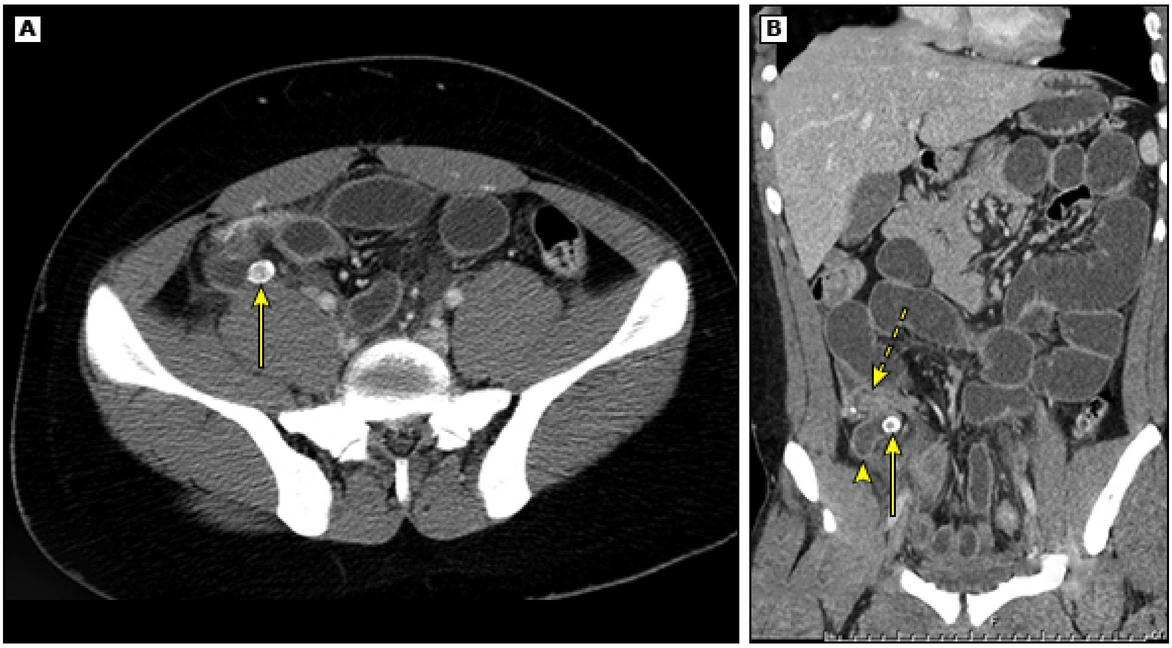


A 13-year-old boy with peri-appendiceal abscess and fecalith. Contrast-enhanced CT scan through the pelvis shows a large calcified fecalith (arrow) within a large inflammatory mass.

Courtesy of George Taylor, MD.

Graphic 95532 Version 1.0

Appendicitis with fecalith on computed tomography



A 17-year-old-male. Axial (A) and coronal reconstructed (B) CT scans show a large calcified fecalith (arrows) at the base of a dilated, fluid filled appendix (arrowhead). Note moderate small bowel dilatation and focal mesenteric edema (dashed arrow).

CT: computed tomography.

Courtesy of George Taylor, MD.

Graphic 95536 Version 2.0

Appendicitis on coronal computed tomography

(A) Retrocecal appendicitis. A six-year-old male. Coronal CT reconstruction (A) shows a large, fluid-filled appendix in sub-hepatic, retrocecal location (arrow). Note localized adenopathy (arrowhead).

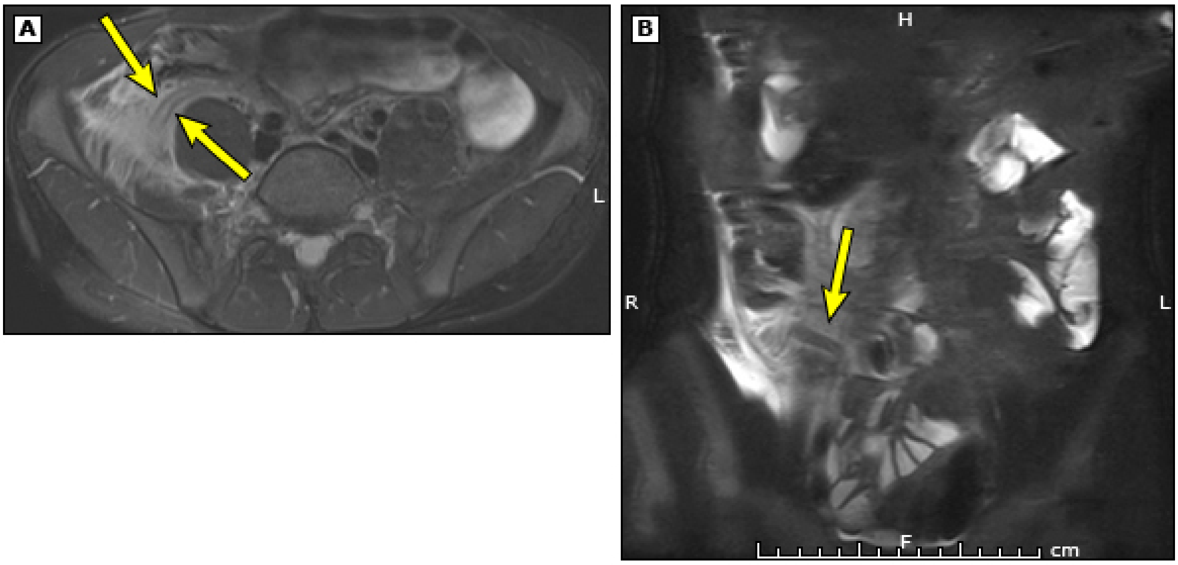
(B) An 11-year-old female. Coronal CT reconstruction (B) shows perforated, fluid-filled, appendix with multiloculated pelvic abscess. Arrow denotes location of perforation.

CT: computed tomography.

Courtesy of George Taylor, MD.

Graphic 95534 Version 2.0

Axial and coronal magnetic resonance images showing appendicitis in a child

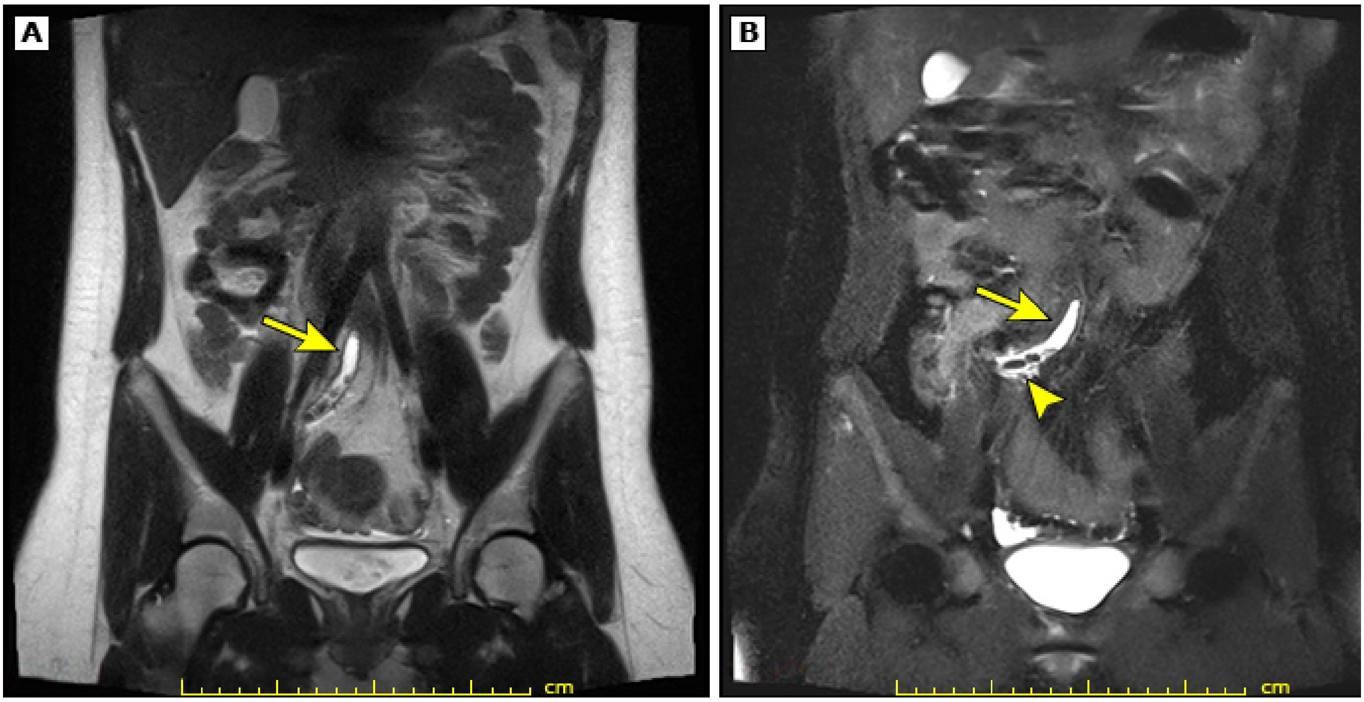


The axial (A) and coronal (B) images show an enlarged and inflamed appendix (arrows). These are noncontrast T-2 images obtained from a three Tesla magnet.

Courtesy of George A Taylor, MD.

Graphic 86410 Version 1.0

Magnetic resonance imaging with appendicitis in an adolescent

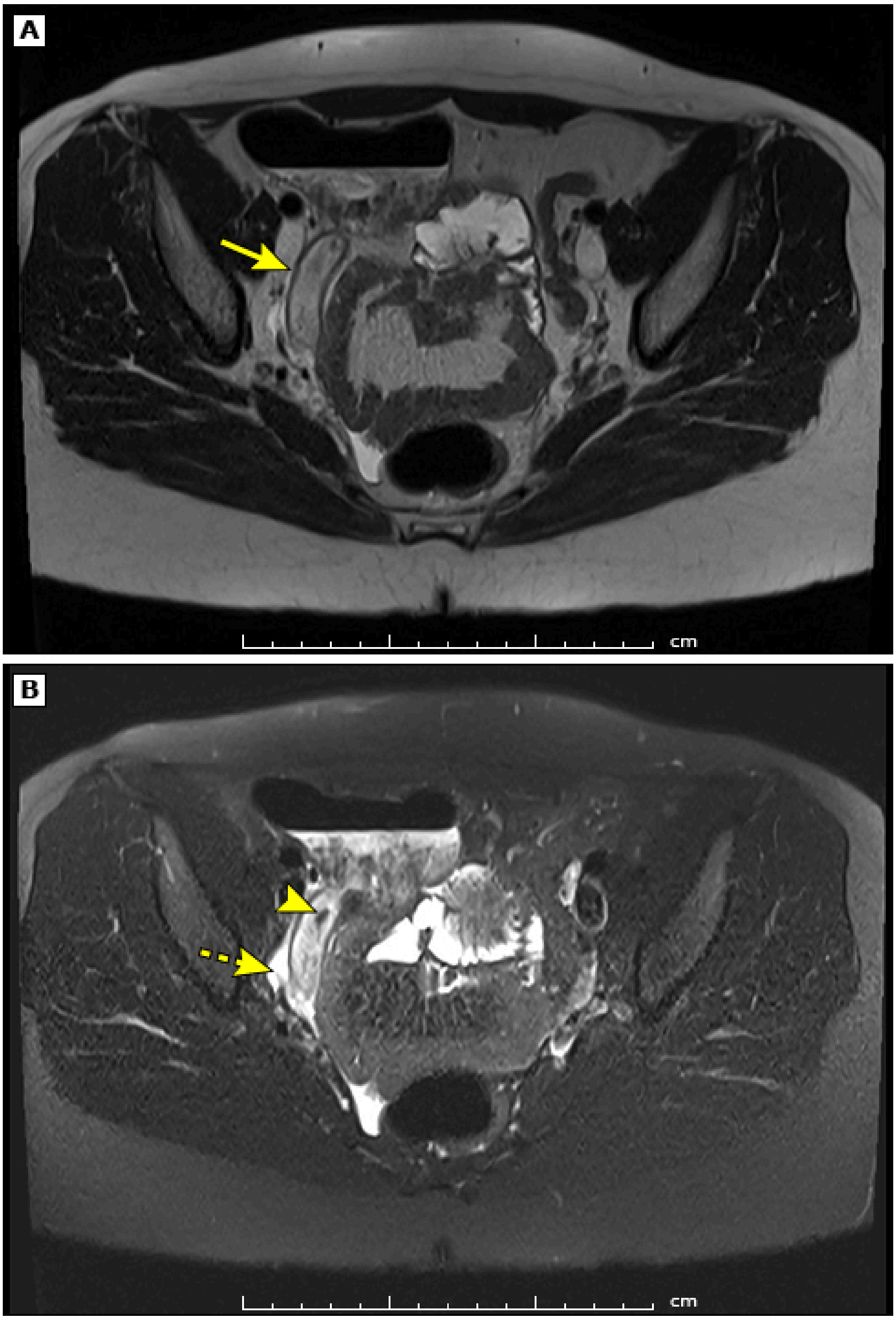


This 15-year-old female presented with right lower quadrant abdominal pain. Coronal T2 (A) and TS Fat saturated (B) sequences demonstrate a dilated, fluid filled appendix (arrow) containing multiple appendicoliths. There is adjacent fat stranding better seen on the fat saturated sequence (arrowhead).

Courtesy of Wendy G Kim, MD.

Graphic 143926 Version 1.0

Magnetic resonance imaging with appendicitis in a 19-year-old female



A 19-year-old female presented with right lower quadrant pain. Axial T2 (A) and T2 fat saturated (B) MRI shows a dilated fluid filled appendix (arrow) with an appendicolith (arrowhead) and adjacent free fluid (dashed arrow).

Courtesy of Wendy G Kim, MD.

Graphic 143927 Version 1.0

Plain radiographic signs of acute appendicitis

Right lower quadrant fecalith
Localized ileus with air/fluid levels
Paucity of gas in the right lower quadrant
Scoliosis concave to the right
Loss of the psoas shadow
Soft tissue mass

Graphic 60537 Version 1.0

Contributor Disclosures

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