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Focus on Diagnosis : Pediatric Abdominal Imaging

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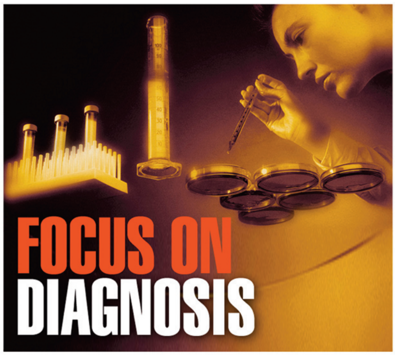

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Pediatric Abdominal Imaging

Kelly M. Clayton, MD*

Introduction

When evaluating acute abdominal pain in children, the most important initial step is to perform a thorough history and physical examination. Only after, if necessary for diagnostic purposes, should specific laboratory and radiographic studies be obtained. Imaging can provide additional evidence to support a questionable diagnosis. A wide variety of abdominal imaging modalities is available to practitioners, although availability is highly dependent on the institution and local resources. We discuss the classic findings indicative of abdominal disorders found on plain radiography, ultrasonography (US), computed tomography (CT) scan, magnetic resonance imaging (MRI), and nuclear medicine studies.

Radiography

Abdominal radiography often is a necessary preliminary study and is the most commonly requested study for a child complaining of abdominal pain. Its availability, lesser cost, and lower radiation exposure compared with other imaging modalities make it attractive. Abdominal radiography is highly sensitive (almost 100%) for diagnosing free intraperitoneal air and bowel obstruction. (1) It may detect abdominal calcifications and foreign body ingestions. Plain radiography for diagnosing intussusception is controversial due to a less than 50% accuracy rate. However, a right upper quadrant soft-tissue mass without right colonic gas is almost pathognomonic for intussusception. (2) Abdominal radiography should not be used to quantify the amount of stool, measure the liver size, or evaluate a child who has chronic vague abdominal pain. (3) It is important to remember that negative findings on abdominal radiography should prompt the physician to order additional, more specific studies when clinical suspicion is high.

Fluoroscopy is used with plain radiography to evaluate the pediatric abdomen. For example, upper gastrointestinal radiographic studies demonstrate both the anatomy and function of the esophagus, stomach, and duodenum. This technique is helpful in diagnosing malrotation, duodenal web, achalasia, and hypertrophic pyloric stenosis. Furthermore, an air contrast enema is not only diagnostic but also the treatment for intussusception.

Ultrasonography

US is a more specific study that should be one of the initial choices when evaluating a child for abdominal pain. It is noninvasive, does not use ionizing radiation, and is relatively inexpensive. US employs high-frequency sound waves to produce real-time images. Its use is easier and more reliable in children than adults because of their small size and diminished fat planes. (4) Higher-frequency transducers also can be used in small children compared with adults, improving the image resolution. (3)

In neonates and younger infants, US is the method of choice to diagnose pyloric stenosis. Its sensitivity and specificity approaches 100% when the pyloric muscle is seen directly. A pyloric muscle thickness of greater than 3 mm is considered positive (Fig. 1), although transient pylorospasm may provide false-positive results. False-negative results also may occur due to an overfilled stomach

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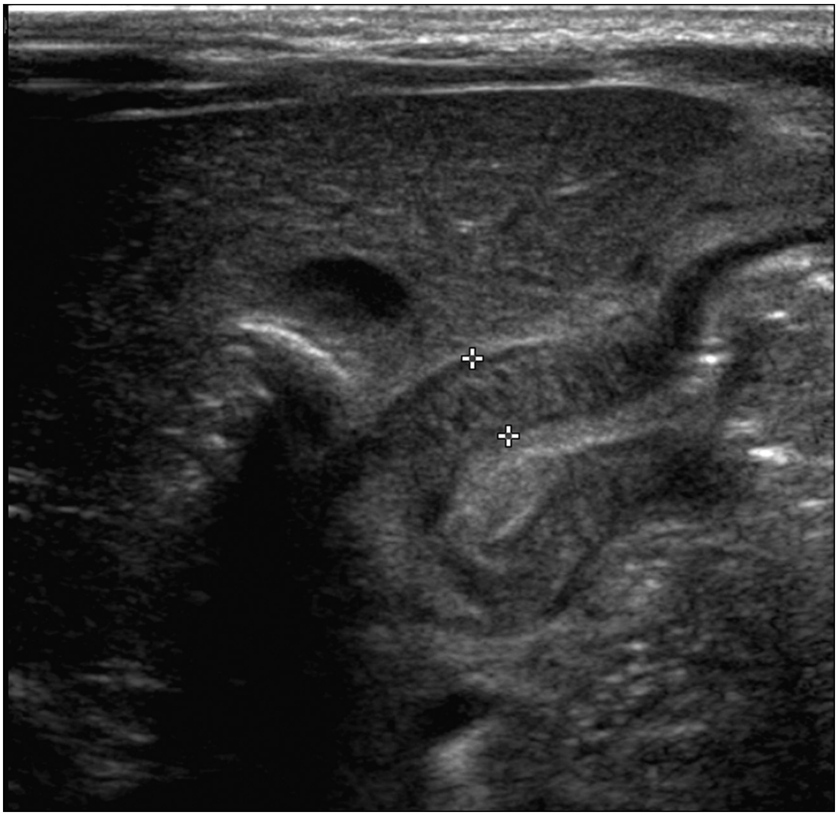

Figure 1. A 4-week-old boy who has had projectile emesis and poor weight gain. Ultrasonography demonstrates a thickened (stars) and elongated pyloric channel, classic findings for pyloric stenosis. Courtesy of Doernbecher Children's Hospital, Portland, Ore.

obscuring the antrum, an inexperienced operator, or a child presenting early in the disease process. (5)

US in older infants and children is useful in diagnosing intussusception, appendicitis, ovarian torsion, and cholelithiasis. It is 100% sensitive and 88% specific for diagnosing intussusception. (6) A hypoechoic thick rim encasing a hyperechoic central core is seen on the transverse section and is the classic "doughnut sign" (Fig. 2). The "sandwich sign" appears on the longitudinal section and is tubular with a hyperechoic lumen and a surrounding hypoechoic layer. Both of these findings on US are diagnostic for intussusception. (7) Additional evaluation and treatment continues with an air contrast enema.

The accuracy of diagnosing acute appendicitis with US varies substantially, depending on the technique of the ultrasonographer. In children, the sensitivity ranges from 44% to 94%, with the specificity between 47% and 95%. (2)(6)(8)(9)(10) Centers experienced in US achieve a sensitivity and specificity of greater than 90%. (11) Demonstrating a noncompressible, aperistaltic, blind-ending tubular structure arising from the cecum on US is diagnostic of acute appendicitis (Fig. 3). Additional criteria include the presence of an appendicolith; periappendiceal fluid; an appendix that has discrete walls, target appearance, or a diameter of greater than 6 mm; and pericecal fat stranding. (10) The one major limitation of US is the inability to see the appendix in up to 20% of cases. (11)

US is the diagnostic test of choice for evaluating pelvic disease. When ovarian torsion is suspected, an enlarged ovary is the most common finding. The ovary usually contains immature follicles on the periphery and may have echogenic areas within that represent stromal edema or hemorrhage. A twisted ovarian vascular pedicle viewed on US is very specific for ovarian torsion. (12) Color Doppler US initially shows decreased or no intraovarian venous flow and progresses to cessation of intraovarian arterial flow when there is a complete torsion.

Finally, cholelithiasis can be diagnosed with the assistance of US. This modality allows for localizing stones, evaluating the gallbladder wall for edema and thickening, and identifying sludge. (13) A Murphy sign also can be elicited with the transducer. Optimal gallbladder examinations have a sensitivity and specificity of greater than 95% for diagnosing cholelithiasis.

In pediatric trauma, the focused assessment with sonography for trauma (FAST) examination is becoming more widely accepted. The FAST examination has a large sensitivity range of 40% to 93% and specificity of 79% to 100%. The FAST examination is used to detect free abdominal fluid that appears anechoic or black. However, the test should not be relied on to detect liver or splenic lacerations. Unfortunately, children have a higher incidence of solid organ damage in the absence of free fluid, and, therefore, a negative FAST study result does not exclude a significant injury. (14)

Overall, US is helpful when evaluating the liver, biliary tract, pancreas, mass lesions, pylorus, and small bowel wall. It is extremely useful in detecting ascites and differentiating

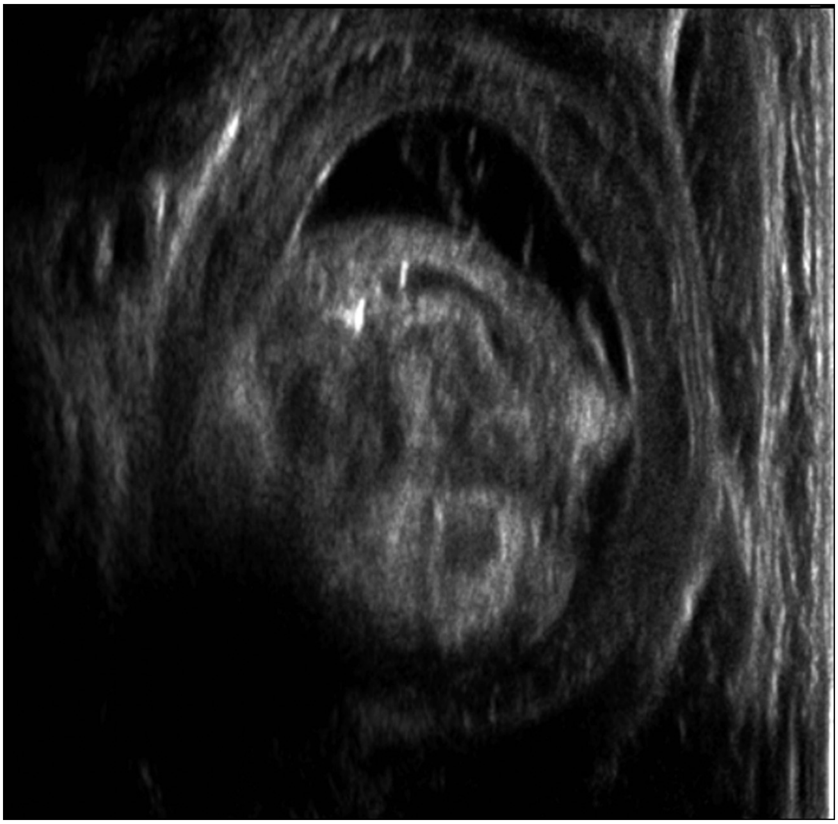

Figure 2. A 9-month-old girl who has had intermittent episodes of lethargy with emesis. Ultrasonography reveals the "doughnut sign," commonly seen with intussusception. Courtesy of Doernbecher Children's Hospital, Portland, Ore.

between solid and cystic structures. However, US is one of the few imaging modalities that is critically dependent on operator skills for high-quality images. Other limiting factors include large body habitus and the presence of bowel gas, which reduce the image quality.

Computed Tomography Scan

CT scan should be used only after other imaging modalities, such as US, have failed to make a definitive diagnosis. CT scan is helpful in recognizing specific disease processes, including nephrolithiasis, appendicitis, intra-abdominal abscesses, and pancreatitis. CT scan allows for measuring and discriminating between tissue densities, is quick to perform, is operator-independent, and presents images in various planes. However, CT scanning can be an invasive procedure that requires intravenous, oral, rectal, or intravaginal contrast. Other disadvantages are the increased amount of radiation when compared with plain radiography. Children are more susceptible to radiation because of the multiple cells in mitosis and they probably will have additional CT scans throughout their lifetimes. (2) Also, there is a possible need for sedation during imaging to decrease motion artifact. Finally, unlike US, a child's small size and lack of fat planes can result in image degradation. (15)

The gold standard imaging modality for diagnosing suspected appendicitis is CT scan. Although different scanning techniques may be used (eg, standard CT with or without intravenous and oral contrast or a focused helical appendiceal CT with or without rectal contrast), the sensitivity, specificity, and accuracy remain greater than 95% for diagnosing appendicitis in children. Surrounding intra-abdominal structures also are visible, allowing recognition of an alternative diagnosis if the appendix appears normal. (10)(11)(16) Key CT scan findings associated with acute appendicitis include an enlarged appendix, a thickened and enhanced appendiceal wall, and periappendiceal fat stranding (Fig. 4). CT scan also may aid in directing percutaneous fluid drainage if an abscess is present.

A nonenhanced helical CT scan is the most sensitive test for diagnosing nephrolithiasis. Contrast should be avoided because of its tendency to conceal stones in the collecting system. CT scan may not only depict calculi and their location, but also can reveal urinary anomalies and complications of ureteral stones. (17)

CT scanning also can be used to diagnose inflammatory bowel lesions, abdominal masses, abdominal trauma, biliary tree or pancreas calcifications, and splenic cysts. Overall, its use should be limited to problems that cannot be detected with less invasive methods, such as US.

Magnetic Resonance Imaging

MRI is another abdominal imaging modality that is noninvasive and does not use ionizing radiation. MRI uses magnets and radio waves to create a magnetic field that is more than 10,000 times that of the earth. However, it is more costly than other imaging modalities, and sedation often is required due to the duration of the study and the need to decrease motion artifact.

A wide range of abdominal disorders can be evaluated by abdominal MRI, which is optimal for viewing

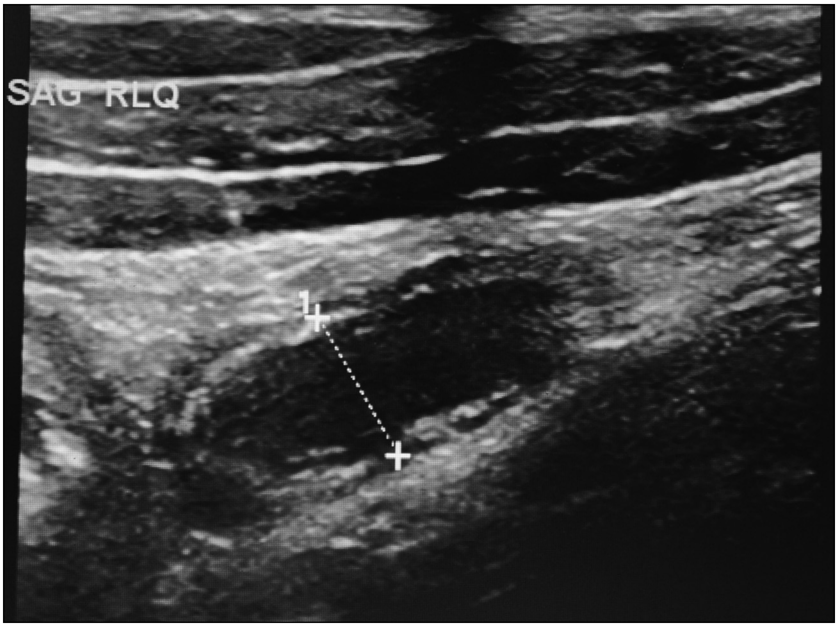

Figure 3. A 15-year-old girl who has had right lower quadrant pain, emesis, and fever. The appendix is unable to be compressed and measures 8 mm in diameter, which is an ultrasonographic sign positive for appendicitis. Courtesy of The Children's Hospital of Alabama, Birmingham, Ala.

the liver and is used to assess hepatic masses. The pancreas, spleen, and kidney also are fairly visible by abdominal MRI. Other uses include demonstrating cystic structures, such as a choledochal cyst; detecting inflammatory lesions; and clarifying findings on abdominal radiographs, US, or CT scan. The bowel is the least well-seen organ on abdominal MRI because of movement degradation caused by peristalsis. However, MRI of the bowel is indicated in patients who require multiple follow-up images and in whom radiation exposure is a concern, as in those who have inflammatory bowel disease. (18) As more studies are performed to improve imaging technique, the indications for abdominal MRI will continue to expand. (3)(15)

Figure 4. An 11-year-old girl who has acute appendicitis and probably rupture. Computed tomography scan shows focal loss of mucosal enhancement at the tip of the appendix (arrow), concerning for wall discontinuity and rupture. Courtesy of Doernbecher Children's Hospital, Portland, Ore.

Nuclear Medicine

Nuclear medicine techniques are unique because of their ability to provide both functional and quantifiable data. These procedures are used for evaluating biliary disease, gastroesophageal reflux, and Meckel diverticula.

The primary indication for hepatobiliary scintigraphy (hepatic 2,6-dimethyliminodiacetic acid or hepatoiminodiacetic acid [HIDA] scan) is obstructive jaundice in a neonate or an older child who has cholestatic jaundice. Hepatocytes take up the substance labeled with technetium 99m, which is injected intravenously and excreted into the biliary tract. Gallbladder filling and biliary tract functioning can be evaluated. Similarly, the radionucleotide in a Meckel scan is absorbed and taken up abnormally by the ectopic gastric mucosa. (2) Nuclear medicine modalities can help quantify gastroesophageal reflux as well as locate the source of occult blood loss from the gastrointestinal tract. (3)(15)

Conclusion

The first step in evaluating abdominal pain in children is performing a history and physical examination. Only after those evaluations should imaging be undertaken to assist the clinician with making and confirming

Table. **Comparison of Imaging Modalities in Gastrointestinal Disease**

Disease	Determining the Diagnosis	
Intussusception	Left lateral decubitus radiographs	US
Appendicitis	US	CT
Gall Bladder/Biliary Disorders	US	
Ovarian Torsion	US	
Nephrolithiasis	Nonenhanced CT	
Pyloric Stenosis	US	UGI
Pancreatitis	CT	
Uncertain of Diagnosis	CT	

CT=computed tomography scan, US=ultrasonography, UGI=upper gastrointestinal radiographic series

a clinical diagnosis. The indications for plain radiographs, US, CT scan, MRI, and nuclear medicine studies in specific abdominal disorders in the pediatric population are summarized in the Table. Additional information may be found in the resources. Further investigational uses should help expand the knowledge and use of imaging modalities in the future.

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