Sonography of the Acute Abdomen in the Pediatric Patient

Diane S. Babcock, MD

Objective. To review the causes and sonographic appearance of pathologic processes that result in abdominal pain in the pediatric patient and to understand the use and limitations of abdominal sonography in the acute pediatric abdomen. ***Methods.*** A pictorial review of cases is presented. ***Results.*** Sonography in conjunction with color and pulsed Doppler imaging is a valuable tool in the evaluation of the acute abdomen in the pediatric patient. This article reviews the use of sonography in the evaluation of the acute abdomen in the pediatric patient. ***Conclusions.*** The causes of the acute abdomen in children vary depending on the ages of the children. Sonography is a noninvasive modality and is useful for assessing these patients. ***Key words:*** abdominal pain; acute abdomen; pediatric sonography.

Abbreviations
GI, gastrointestinal

Received May 10, 2002, from the Department of Radiology, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio. Manuscript accepted for publication May 13, 2002.

Address correspondence and reprint requests to Diane S. Babcock, MD, Department of Radiology, Cincinnati Children's Hospital Medical Center, 3333 Burnet Ave, Cincinnati, OH 45229-3039.

The causes of the acute abdomen in children vary depending on the ages of the children and can be divided into diseases that can be treated with medical care and those in which emergency surgical intervention must be considered.[1] The role of diagnostic imaging is to determine whether the acute abdominal pain is due to a surgically or medically treated disease and if possible to diagnose the exact nature of the ailment. Imaging usually begins with a supine and horizontal beam radiograph. A chest radiograph is also commonly included to show extra-abdominal causes of acute abdominal pain such as pneumonia. Because of the noninvasive nature of sonography and its sensitivity in finding the common lesions producing acute abdominal disease, it is often the next imaging procedure performed. Doppler sonography is helpful for assessing organ perfusion and diagnosing inflammation.

The Acute Abdomen in the Neonate

Premature Neonate

Necrotizing enterocolitis is a serious abdominal disorder of premature neonates, which most often affects the terminal ilium and ascending colon. Clinical symptoms include abdominal distention and hematochezia as well as apnea, acidosis, temperature instability, and lethargy. Diagnosis is usually made on the basis of abdominal radiographs showing pneumatosis, a thick-walled bowel, free air, and portal venous air. Sonography may be useful when perforation and abscess formation are suspected.[2] The examination can be performed portably in the neonatal intensive care unit with excellent resolution of bowel anatomic characteristics when high-frequency (7- to 10-MHz) transducers are used. Mural thickening of the terminal ilium and ascending colon may be shown. Free intra-abdominal fluid containing echogenic debris (Fig. 1) or a loculated right lower quadrant mass suggests perforation and abscess formation. Portal venous gas may be visualized as well.

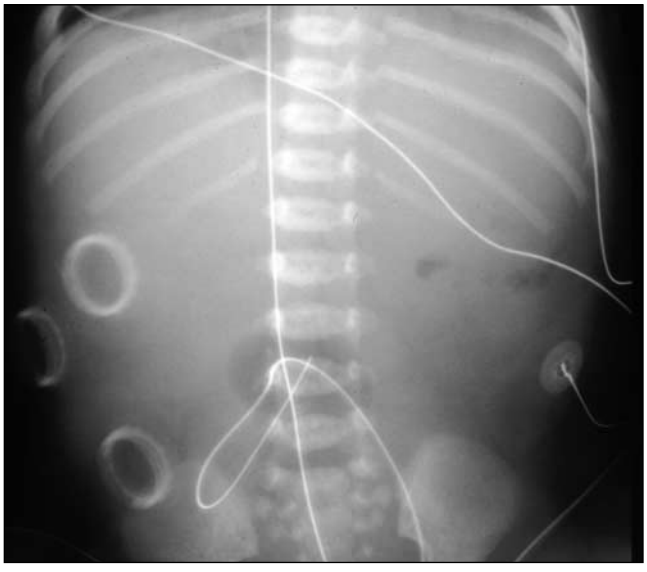
Full-Term Neonate

Congenital intestinal obstruction is the most common condition producing a distended and tender abdomen in an irritable neonate. A paralytic ileus caused by septicemia must also be considered in the differential diagnosis. Diagnosis of obstruction is usually made by plain radiographs and contrast studies. Sonography can be helpful in the diagnosis of small-bowel obstruction particularly in the gasless abdomen by confirming the presence and location of distended, fluid-filled bowel loops (Fig. 2).[3] Malrotation can be suggested when the positions of the superior mesenteric artery and vein are reversed (Fig. 3).[4]

The Acute Abdomen in the Infant

After the neonatal period, a different set of diseases produces the acute abdomen. Intussusception is particularly common in the 1-month to 2-year age group. A strangulated inguinal hernia, complicated Meckel diverticulum, and malrotation with volvulus are surgically treated causes. Appendicitis is less common in this age group than in the older child but can occur. Non–surgically treated causes, including primary peritonitis, colic, and gastroenteritis, are more common and must be differentiated.

Ileocolic intussusception with invagination of the ileum through the ileocecal valve into the colon occurs predominately in the first 2 years of life. Pathologic lead points such as lymphoma and gastrointestinal (GI) duplication should be considered in children older than 3 years. The diagnosis and nonsurgical reduction



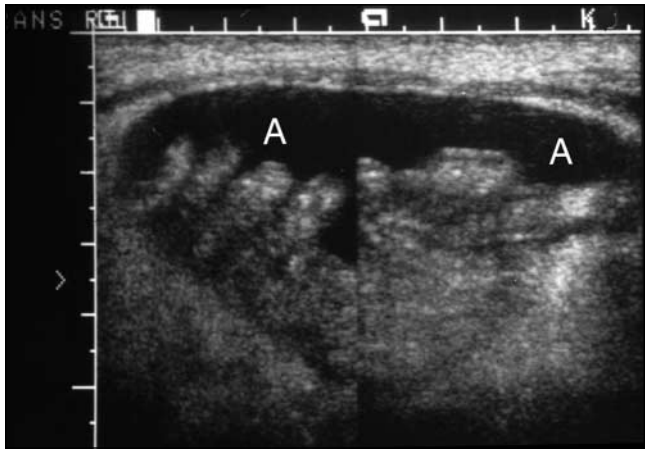


Figure 1. Premature neonate with necrotizing enterocolitis, bowel perforation, and a gasless abdomen. **A**, Supine radiograph shows paucity of bowel gas. **B**, Transverse abdominal scan shows free intra-abdominal fluid (A).

of intussusception is generally performed with air, barium, or water-soluble contrast material under fluoroscopic guidance.[5] Sonographically guided hydrostatic reduction of intussusception has been described by Riebel et al[6] and recommended because of a substantial reduction in radiation exposure. Intussusception can be recognized on sonography by visualization of a mass with a typical "target" appearance on a cross section, due to multiple layers of bowel, and a pseudokidney appearance on longitudinal scans (Fig. 4).[7] Negative sonographic findings can exclude intussusception with near 100% accuracy, enabling selection of those patients in need of enemas.[8] Doppler sonography can be used to evaluate bowel ischemia and risk of perforation. Ischemic bowel,[9] entrapped fluid,[10] and interloop lymphadenopathy[11] make successful reduction less likely. Fluoroscopically guided reduction with air insufflation is preferred in North America.

An inguinal hernia may incarcerate and appear as an acute abdomen. Sonography of the scrotum and inguinal area may be used to confirm the diagnosis (Fig. 5). The presence of bowel loops may be evident; however, the hernia may contain omentum and may be difficult to diagnose. Other abdominal structures such as the ovary may herniate into the inguinal area and become entrapped (Fig. 6).

Figure 2. Sonogram of a neonate with small-bowel obstruction. Asterisks indicate dilated fluid-filled bowel loops.

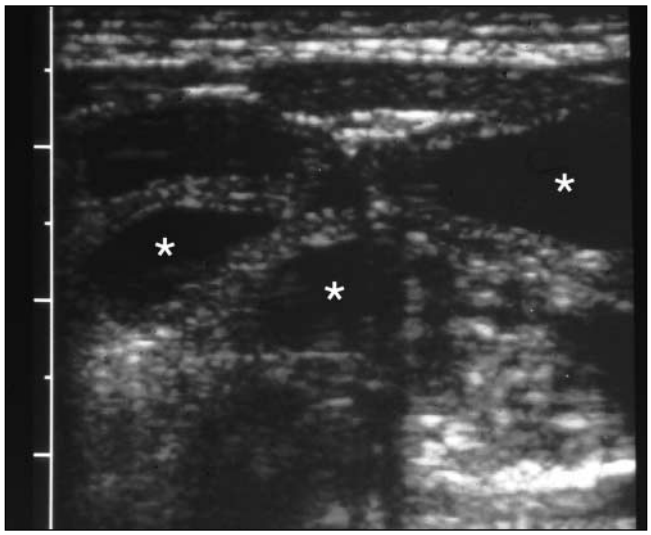
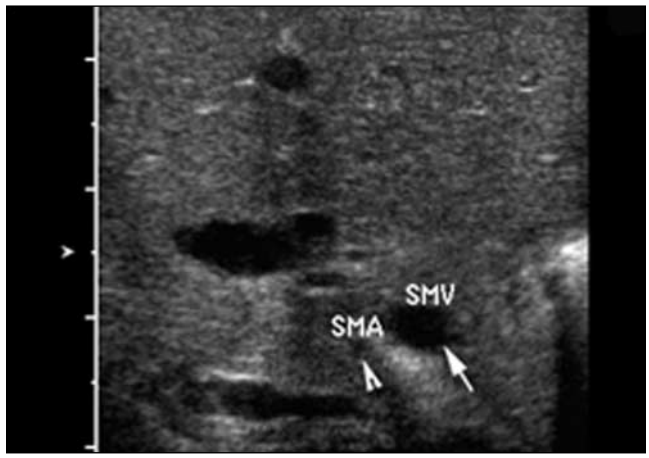
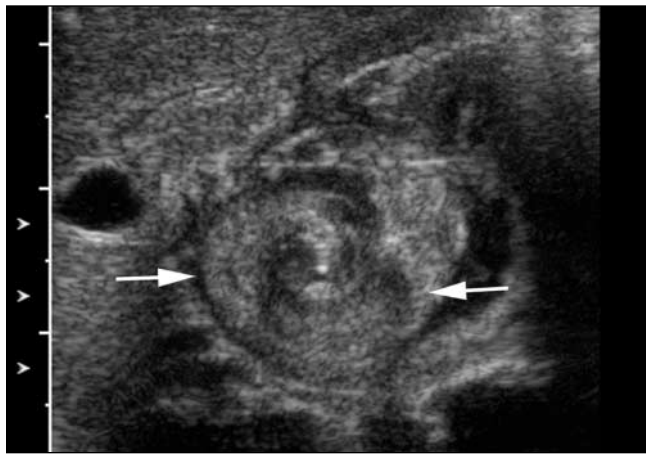


Figure 3. Malrotation. **A**, The positions of the superior mesenteric artery (SMA; arrowhead) and vein (SMV; arrow) are reversed. **B**, Neonate with malrotation and midgut volvulus. Transverse scan of the upper abdomen shows an abnormal thick-walled bowel loop (arrows). **C**, Color Doppler image shows spiraling of superior mesenteric vessels.

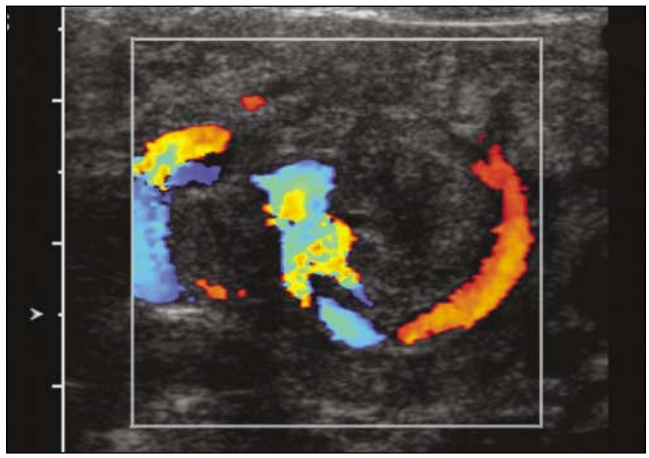
A



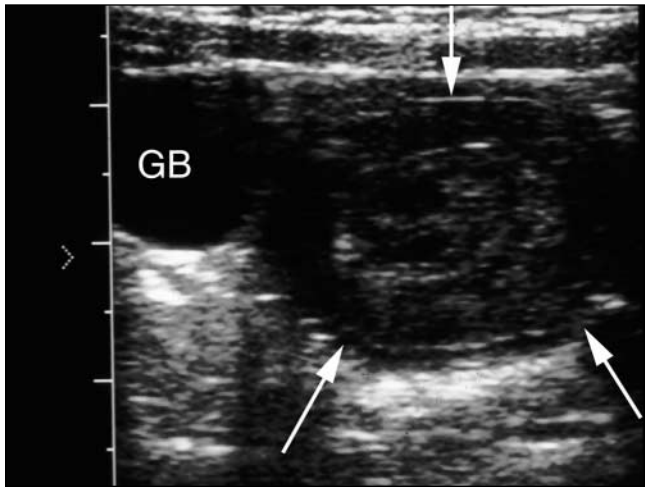
B



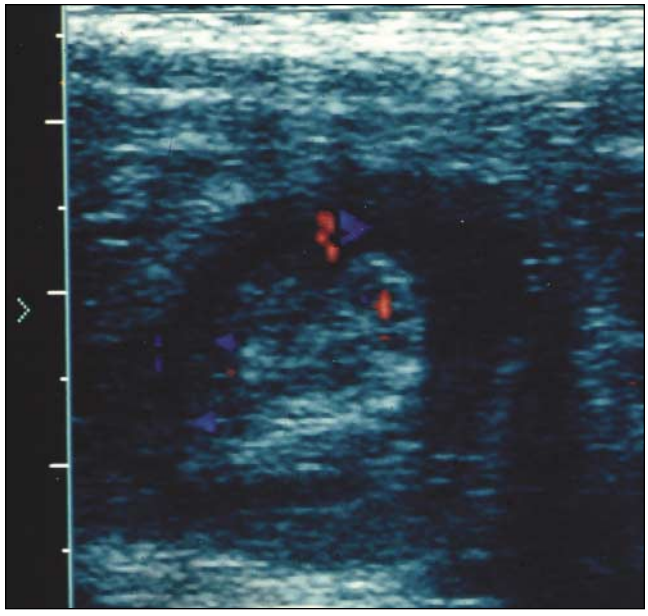
C



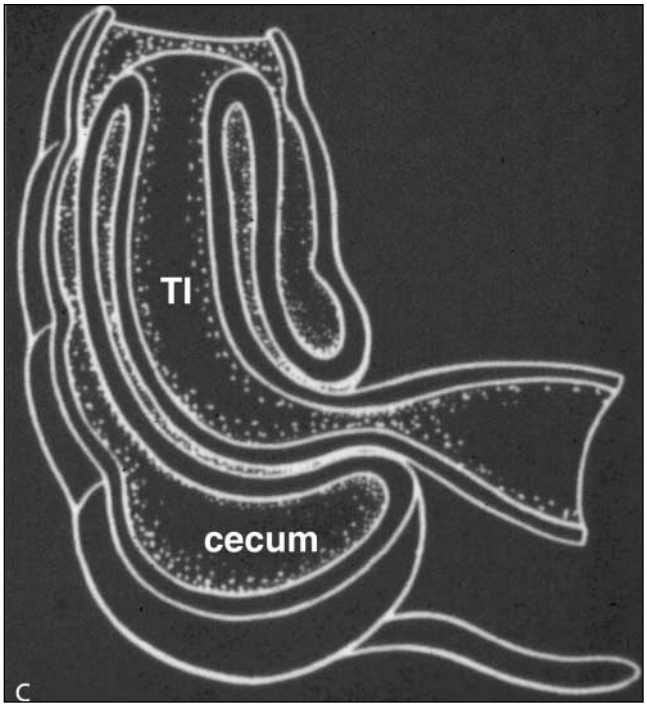
A



B



D



C

E

Figure 4. Intussusception. **A**, Radiograph shows dilated bowel and a soft tissue mass in the right upper quadrant (arrows). **B**, Longitudinal scan of the right upper quadrant shows the mass (arrows) with a target appearance adjacent to the gallbladder (GB). **C**, Diagram of ileocolic intussusception. TI indicates terminal ileum. **D**, Color Doppler image shows blood flow within the intussusception. **E**, Surgical specimen.

The Acute Abdomen in the Child and Adolescent

Causes of abdominal pain in the child differ from those in the infant, and acute appendicitis is the most common surgically treated condition. The child, particularly the older child and teenager, can verbalize the location of the pain, thereby narrowing the differential diagnosis. The imaging examination can be tailored to look for specific diseases associated with the location of the pain.

Right Upper Quadrant Pain

Gallbladder disease, hepatitis, pyelonephritis, renal colic, and acute hydronephrosis are suggested by right upper quadrant pain. Gallbladder dilatation can occur with sepsis or lack of enteral feeding and may or may not be associated with pain. Gallbladder dilatation is suggested when the length of the gallbladder is greater than the normal right kidney and when the diameter is greater than 4 cm (Fig. 7). Acute acalculous cholecystitis occurs in children in association with septicemia, dehydration, streptococcal infections, and Kawasaki disease. Sonography shows gallbladder wall thickening and tenderness when scanning over the gallbladder (Fig. 8).

Cholelithiasis can occur in children. Predisposing diseases include hemolytic anemia, cystic fibrosis, metabolic disease, liver disease, malabsorption before orthopedic surgery, and others (Fig. 9).[12] Gallbladder sludge may be shown with lack of enteral feeding or diuretic therapy and often clears when the patient returns to a normal diet.

Hepatitis and pyelonephritis are diagnosed on the basis of clinical symptoms, blood tests, and urinalysis. Imaging is often unnecessary. Renal diseases such as acute dilatation caused by calculous disease or obstruction at the ureteral-pelvic junction can cause an acute abdomen, and sonographic examination shows dilatation of the collecting system (Fig. 10).

Left Upper Quadrant Pain

Disorders of the spleen such as splenomegaly and torsion or renal disorders such as pyelonephritis, hydronephrosis, and renal colic can cause left upper quadrant pain. With splenic torsion, sonography shows an abnormal location of the spleen in the mid or lower abdomen (Fig. 11) and decreased flow on Doppler imaging. Enlargement of the spleen is suggested when the lower pole extends below the ribs. Splenic infarction may occur, especially in sickle cell disease, and may show abnormal echogenicity or areas of abnormal perfusion on Doppler imaging (Fig. 12).[13]

Abdominal pain in the epigastrium can result from pancreatic disease and, less commonly, from gastric and duodenal ulcers. Causes of pancreatitis in children include blunt abdominal trauma, infection, drug toxicity, biliary-pancreatic tract anomalies, and others. With acute

Figure 5. Inguinal hernia. Longitudinal scan of the right scrotum and inguinal area shows normal testes (T) with hydrocele. A bowel loop (arrowheads) containing air is also shown. Note the typical appearance of bowel wall with 5 layers.

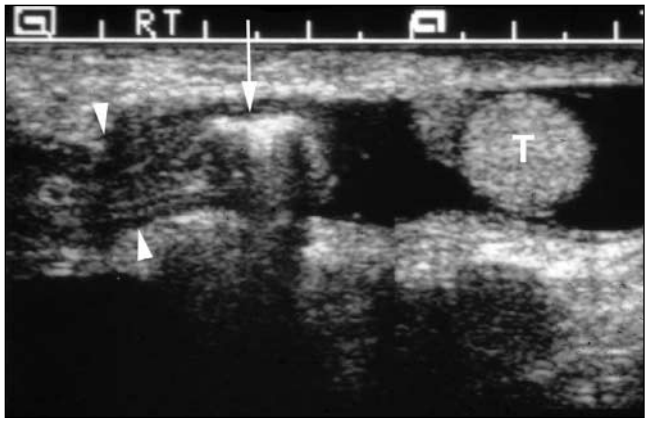
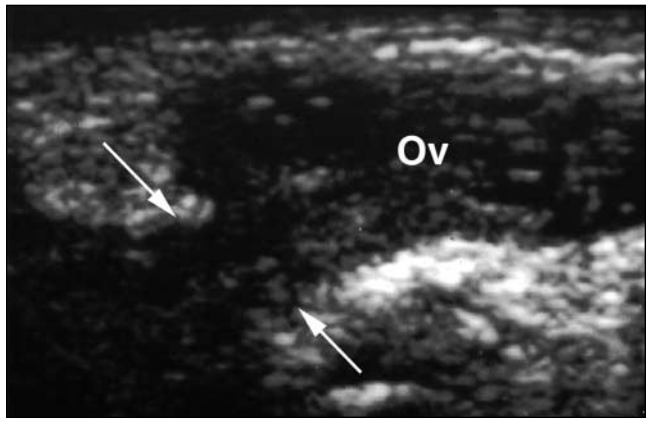


Figure 6. Hernia containing ovary. Longitudinal view of the inguinal area shows the ovary (Ov) containing small follicles. Arrows indicate the inguinal canal.



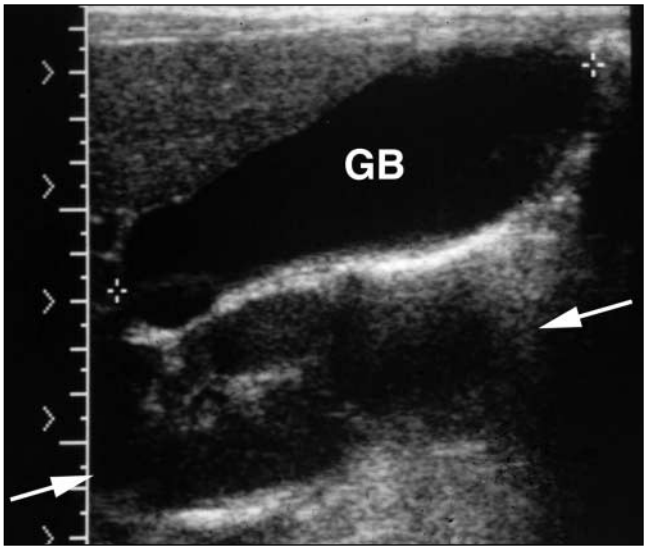


Figure 7. Image from a 7-year-old patient with Kawasaki disease and gallbladder hydrops. Longitudinal view of right upper abdomen shows a large gallbladder (GB) measuring 11.4 cm, larger than the adjacent right kidney (arrows).

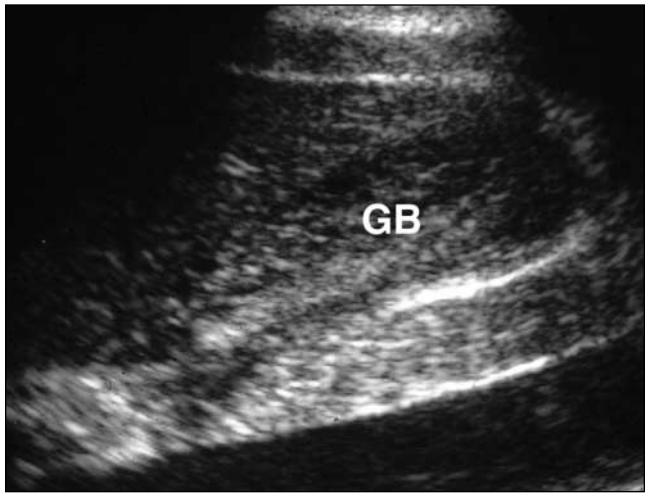


Figure 8. Acalculous cholecystitis. Longitudinal view of the right upper abdomen shows a large gallbladder (GB) with a thick wall and echogenic debris.

pancreatitis, the pancreas may be enlarged and abnormally hypoechoic. The pancreatic duct may be dilated (Fig. 13). However, it should be cautioned that a child's pancreas is normally relatively larger and less echogenic than an adult's pancreas (Fig. 14). Fluid collection (pseudocysts) can form around the pancreas, particularly adjacent to the tail (Fig. 15).[14] Although sonographic findings in ulcer disease have been described, the diagnosis is usually made on the basis of contrast upper GI studies.

Right Lower Quadrant Pain

Acute appendicitis is the most common acute surgically treated ailment in infants and children and usually presents as pain localized to the lower right quadrant. The diagnosis can often be made on the basis of a physical examination and elevated white blood cell count. Imaging is used in atypical or uncertain cases. Plain film radiography is useful if an appendicolith is visualized but may show a normal appearance in about half of cases.[15] The appendix can be directly visualized by sonography with graded compression of the right

Figure 9. Gallstones. Longitudinal view of gall bladder shows echogenic filling defects (arrows) and acoustic shadowing (S).

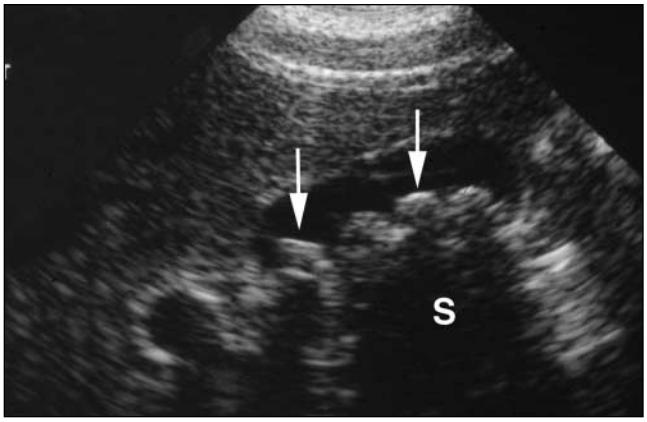
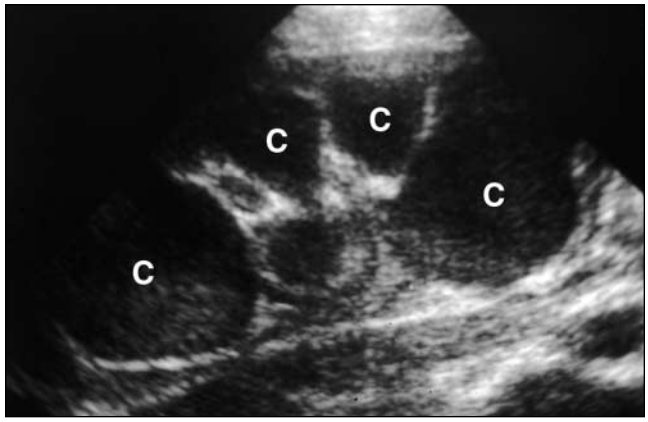
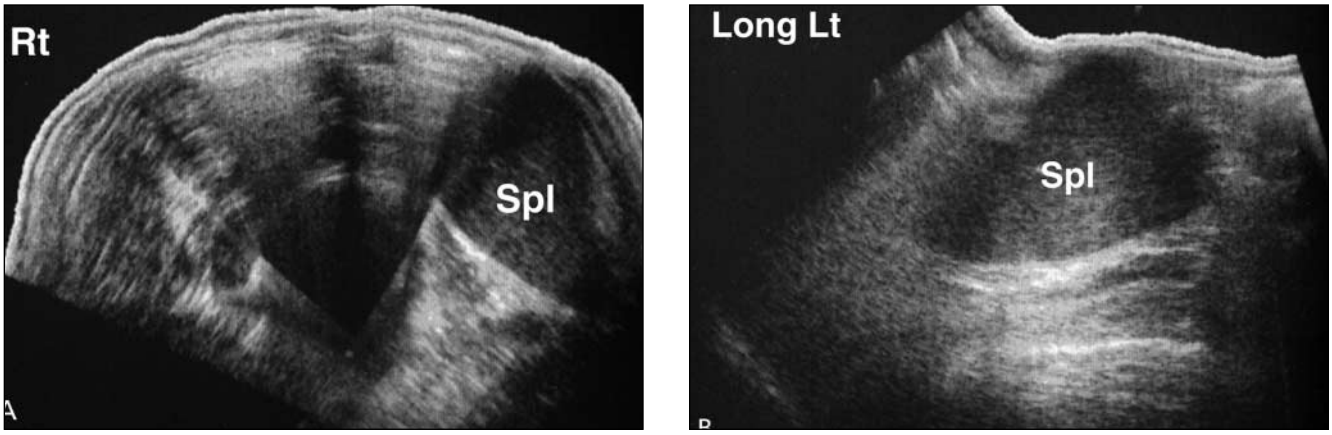


Figure 10. Pyelonephrosis with ureteral-pelvic junction in a 14-year-old patient with fever and costovertebral angle pain. Longitudinal sonogram of the right kidney shows marked hydronephrosis with echogenic material within the collecting system (C).





A B

Figure 11. Splenic torsion in a 9-year-old patient with abdominal pain. Transverse (**A**) and longitudinal (**B**) sonograms of the abdomen show a low position of the spleen (Spl) in the left midabdomen. No perfusion was present.

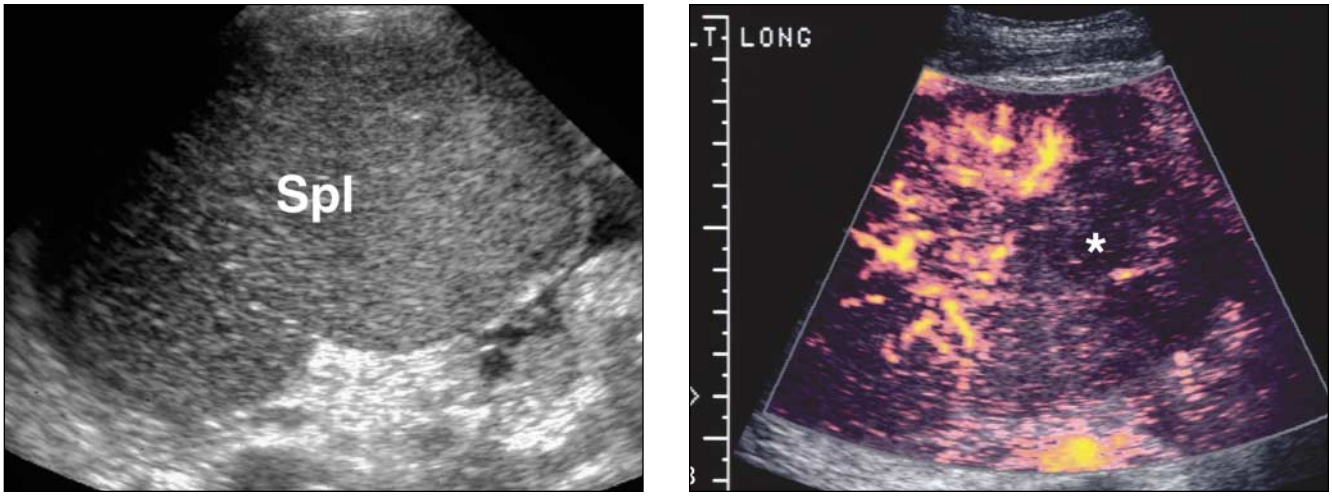
lower abdomen. Overall sensitivity of 85% and specificity of 92% have been reported.[16] Computed tomography is used in large patients who are not good candidates for sonography and when sonography is not definitive.

The inflamed appendix is recognized as a sausage-shaped, blind-ended structure on longitudinal images and as a target lesion on transverse images (Fig. 16). An appendix that is greater than 6 mm in diameter and noncompressible suggests acute appendicitis. Indistinctness of the layers, periappendiceal fluid collection (Fig. 17), and echogenic surrounding mesentery may also be shown. Identification of a normal appendix less than 6 mm in diameter makes the diagnosis of appendicitis very unlikely. The normal appendix is not always visualized, however. Doppler imaging may aid in the diagnosis, because the acutely inflamed appendix shows increased flow compared with normal bowel.[16]

Inflammatory bowel disease and gynecologic disorders may also cause pain in the right lower quadrant, and sonography is particularly useful in girls to distinguish appendiceal disease from gynecologic disorders.

Figure 12. Splenic infarct in a patient with abdominal pain who had a liver transplant. **A**, Longitudinal sonogram shows an enlarged spleen (Spl) with minimally heterogenous echogenicity. **B**, Power Doppler sonogram shows decreased perfusion (*) throughout the lower pole.

A B



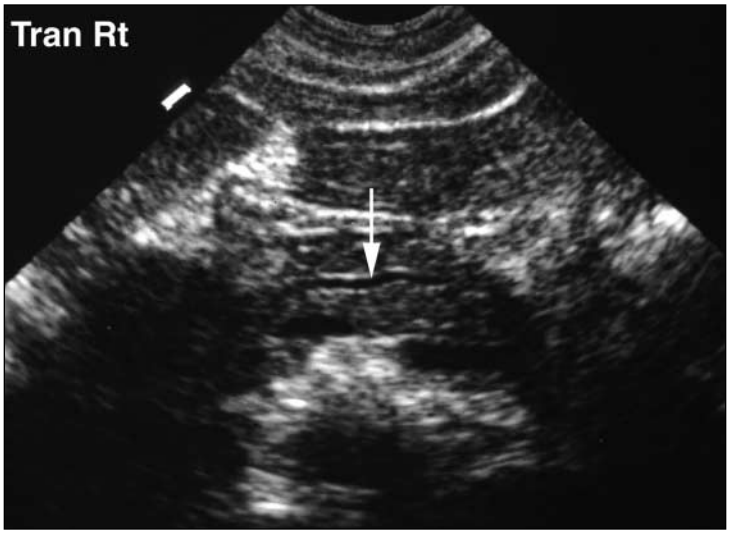


Figure 13. Acute pancreatitis in a 10-year-old patient with abdominal pain. Transverse sonogram shows a mildly enlarged pancreas with a dilated pancreatic duct (arrow).

Midabdominal Pain

Bowel obstruction, malrotation with volvulus, and intussusception can cause midabdominal pain. These disorders are best diagnosed on plain film radiography (Fig. 3) and contrast studies of the GI tract. Hemorrhage into the bowel wall can occur in bleeding disorders such as Henoch-Schönlein purpura and can result in thick-walled bowel loops on sonography. Small-bowel intussusceptions, which are visible on sonography, can also develop in these patients. The finding of unusual-appearing masses and hematoma in patients without bleeding disorders should raise the possibility of hematoma from child abuse (Fig. 18).[17]

Mesenteric adenitis from a variety of infections, usually viral, can be associated with abdominal pain.[18] Sonography shows enlarged mesenteric lymph nodes (Fig. 19) and can exclude other conditions such as an inflamed appendix.

Acute dilatation of the renal pelvis (hydronephrosis) can produce abdominal pain, which may be noted in the midabdomen. The obstruction is usually at the ureteropelvic junction. Sonography may be used to exclude this diagnosis.

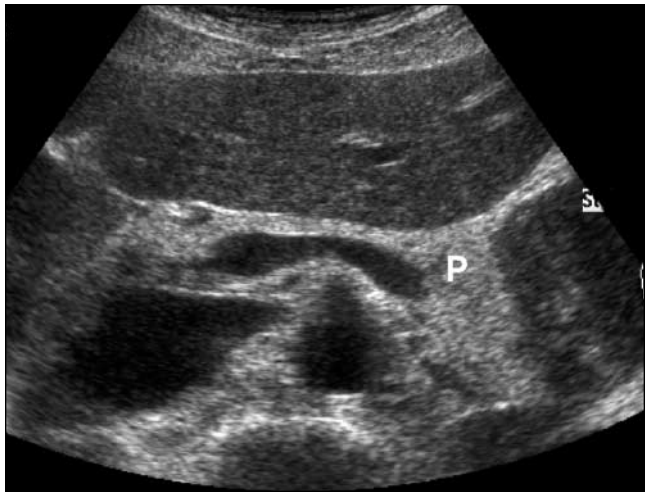
Gynecologic Disorders

Acute abdominal pain can be caused by gynecologic disorders, particularly in adolescent girls. Right-sided disorders may cause symptoms similar to acute appendicitis and may be difficult to differentiate clinically. Disorders include hemorrhagic ovarian cysts, ovarian torsion, pelvic inflammatory disease or abscess, ectopic pregnancy, and, infrequently, endometriosis.[19] Sonography is useful in showing the normal or abnormal ovary and uterus, abnormal fluid collections, and masses. Follicles are commonly shown in the pediatric ovary. Hemorrhage into a follicular cyst is shown as an ovarian mass with no internal flow (Fig. 20).

Figure 14. Normal pancreas. **A**, Transverse scan in a child shows normal pancreas (P) echogenicity, equal to that of the liver. **B**, The normal adult pancreas is relatively smaller and more echogenic.

A

B



It may be difficult to distinguish from a torsed normal ovary, which also appears as a mass with no or diminished flow (Fig. 21).[20]

Non–Surgically Treated Disorders

Abdominal pain in the child can be caused by non–surgically treated disorders, including gastroenteritis, primary peritonitis, and constipation (Fig. 22). A common syndrome is chronic recurrent abdominal pain of a functional nature. The pain is recurrent and may be severe, usually located in the periumbilical or epigastric region. Physical examinations, laboratory studies, and imaging examinations are unrevealing. Sonography can be used to rule out other organic causes of abdominal pain, and negative examination findings may be reassuring to the family.[21]

Referred Pain

Causes of referred pain that may appear as an acute abdomen include diseases of the spine and chest and metabolic diseases such as sickle cell anemia. Other diseases should be suspected if abdominal imaging findings are negative. Pneumonia involving the lower lobes may occasionally be diagnosed on the basis of sonography by serendipitous visualization of an abnormal nonaerated lung above the diaphragm (Fig. 23).

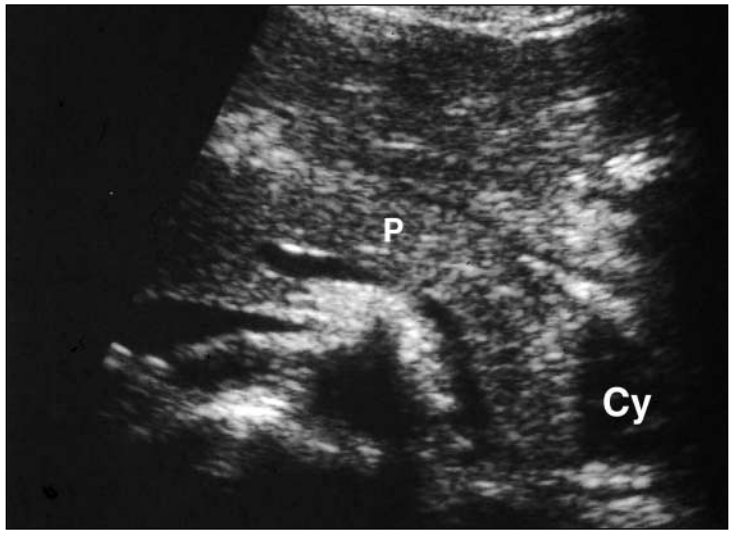
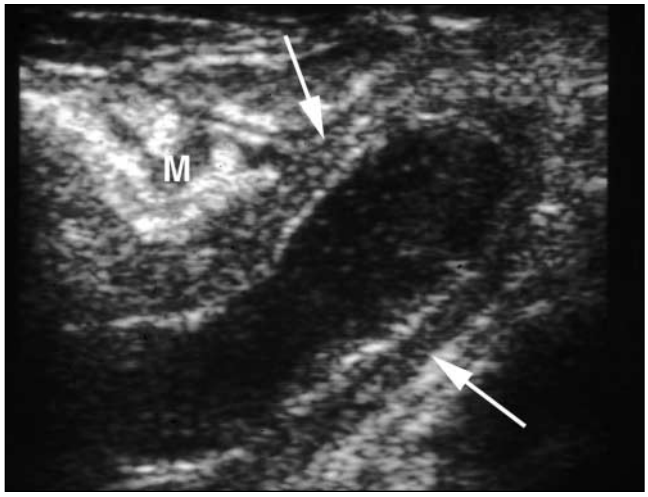


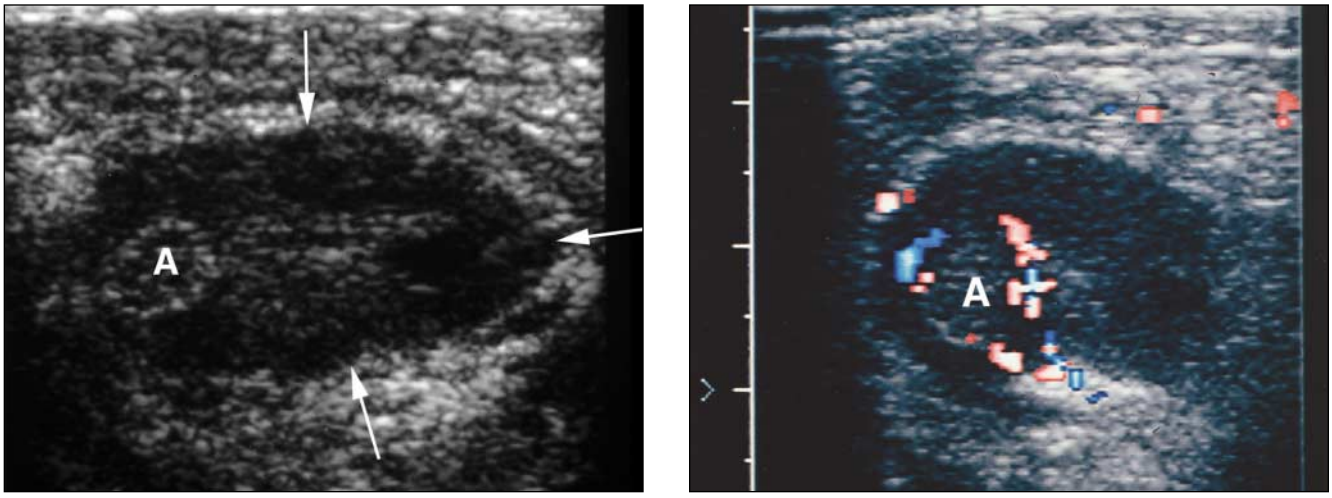
Figure 15. Pancreatic pseudocyst. Transverse scan shows a mildly enlarged pancreas (P) with loculated fluid collection (Cy) adjacent to the tail.

Figure 16. Appendicitis in a 9-year-old patient with right lower quadrant pain. **A**, Sonogram of the right lower quadrant shows a dilated, noncompressible, fluid-filled appendix (arrows) measuring 1.5 cm. The adjacent mesentery (M) is inflamed and echogenic. **B**, Pathologic specimen of the inflamed appendix.

A



B



A B

Figure 17. Appendicitis with perforation in a 9-year-old patient with a 5-day history of abdominal pain. **A**, Sonogram shows a right lower quadrant mass with a dilated appendix (A) having indistinct margins and adjacent hypoechoic fluid collections (arrows). **B**, Color Doppler sonogram shows increased blood flow in the inflamed appendix (A).

Conclusions

Sonography continues to be an effective modality for evaluating the acute abdomen in the pediatric patient. The cause of the acute abdomen varies depending on the age of the child. Imaging usually begins with a supine and horizontal beam radiograph. Because it uses nonionizing radiation and is noninvasive, sonography is often the next imaging procedure performed. In this review, we have presented the sonographic findings of the most common pathologic entities.

Figure 18. Hematoma in 3-year-old patient with abdominal pain and nonaccidental trauma. **A**, Transverse sonogram of the right upper abdomen shows a heterogeneous mass (M) adjacent to the duodenum. **B**, Upper GI image shows a narrow duodenal channel with intramural hematoma.

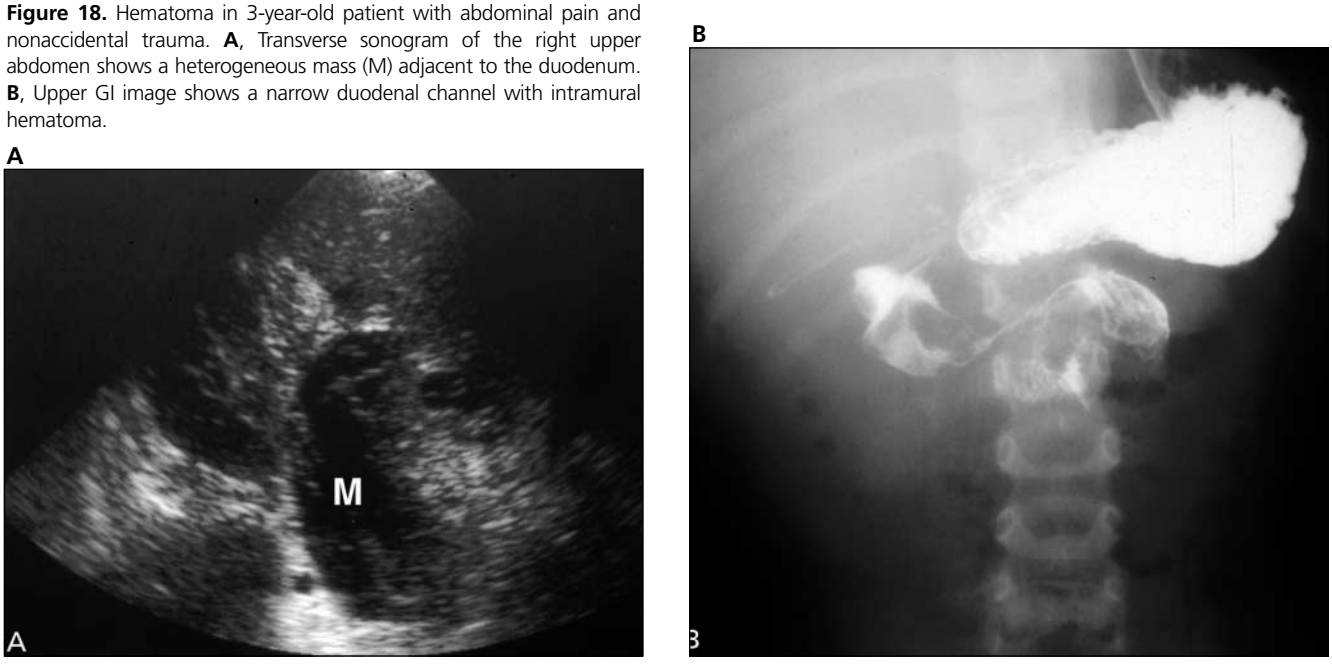


Figure 19. Mesenteric adenitis in a 9-year-old patient with right lower quadrant pain. **A**, Sonogram shows multiple oval mesenteric masses consistent with enlarged lymph nodes (A). **B**, Color Doppler sonogram shows typical hilar blood vessel in enlarged lymph node.

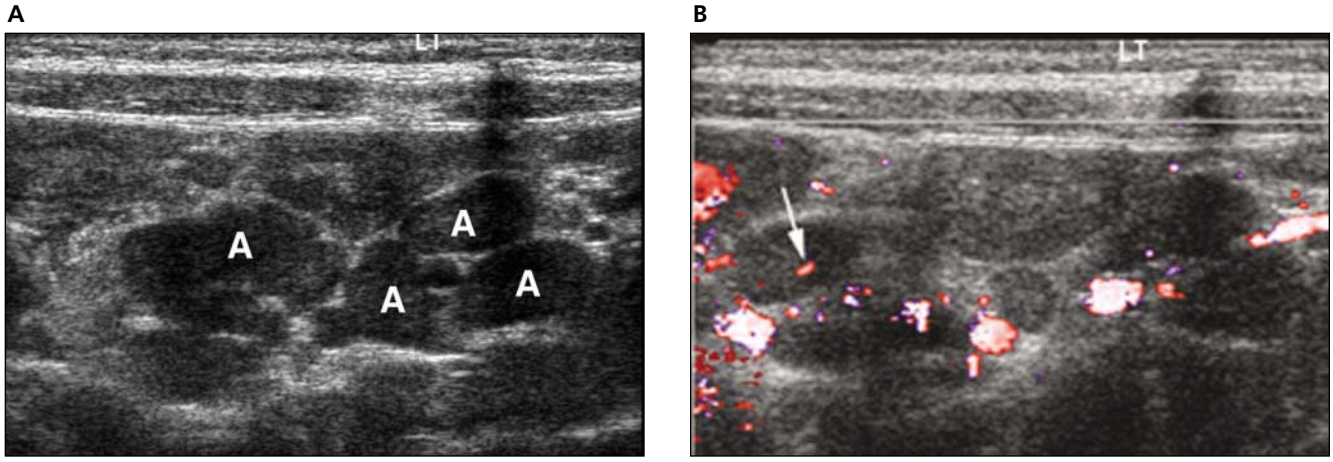


Figure 20. Hemorrhagic ovarian cyst in an adolescent patient with right lower abdominal pain. **A**, Transverse sonogram shows an enlarged right ovary with a heterogeneous mass (arrows). **B**, Color Doppler sonogram shows blood flow in ovarian tissue around the periphery of the mass.

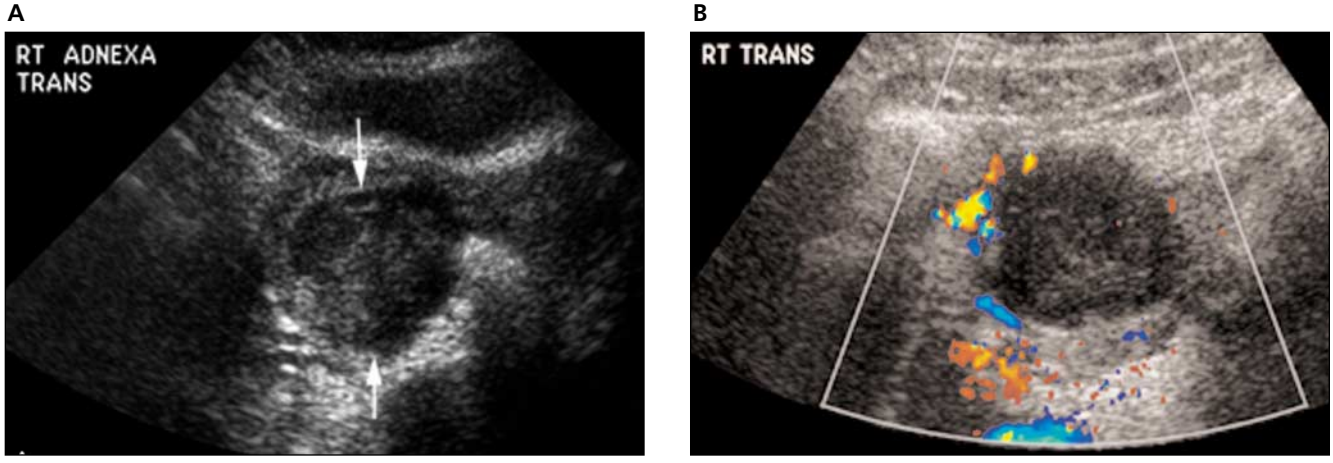
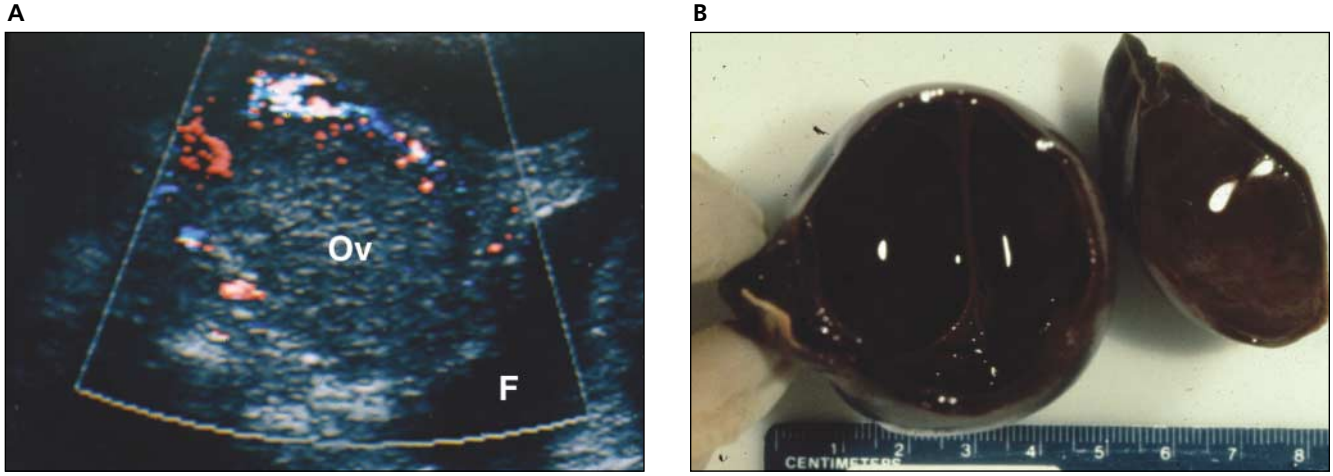


Figure 21. Ovarian torsion in a 3-year-old patient with lower abdominal pain. **A**, Pelvic color Doppler sonogram shows an enlarged ovary (Ov) with no central blood flow. Vessels are shown in ligaments adjacent to ovary. Free fluid in the pelvis (F) is also shown. **B**, Pathologic specimen of the torsed ovary containing a hemorrhagic cyst.



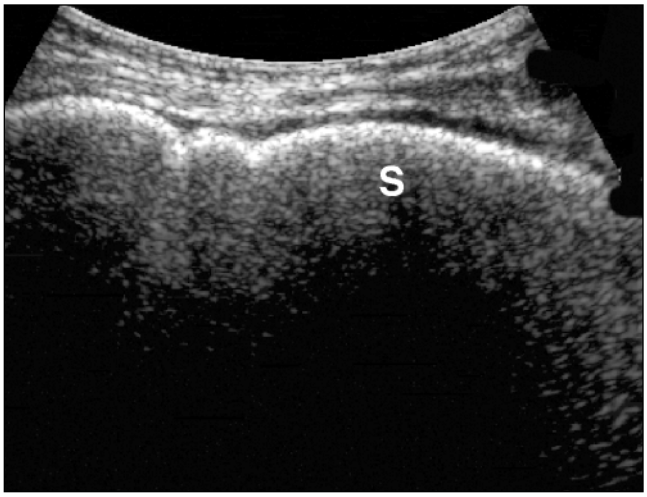


Figure 22. Constipation in a 3-year-old patient with abdominal pain. Longitudinal sonogram of the lower abdomen shows echogenic stool (S) and no through-transmission.

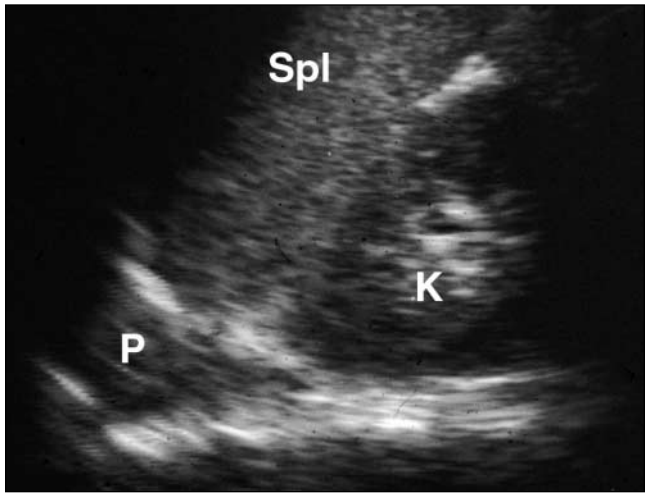


Figure 23. Pneumonia in a 9-year-old patient with left flank pain. Longitudinal sonogram of the left upper quadrant shows echogenic left lower lobe pneumonia (P). The spleen (Spl) and left kidney (K) are normal.

References

1. Franken EA Jr, Kao SC, Smith WL, Sato Y. Imaging of the acute abdomen in infants and children. AJR Am J Roentgenol 1989; 153:921–928.
2. Miller SF, Seibert JJ, Kinder DL, Wilson AR. Use of ultrasound in the detection of occult bowel perforation in neonates. J Ultrasound Med 1993; 12:531–535.
3. Seibert JJ, Williamson SL, Golladay ES, Mollitt DL, Seibert RW, Sutterfield SL. The distended gasless abdomen: a fertile field for ultrasound. J Ultrasound Med 1986; 5:301–308.
4. Chao H, Kong M, Chen J, Lin SJ, Lin JN. Sonographic features related to volvulus in neonatal intestinal malrotation. J Ultrasound Med 2000; 19:371–376.
5. McAlister WH. Intussusception: even Hippocrates did not standardize his technique of enema reduction. Radiology 1998; 206:595–598.
6. Riebel TW, Nasir R, Weber K. US-guided hydrostatic reduction of intussusception in children. Radiology 1993; 188:513–516.
7. del-Pozo G, Albillos JC, Tejedor D. Intussusception: US findings with pathologic correlation—the crescent-in-doughnut sign. Radiology 1996; 199: 688–692.
8. Verschelden P, Filiatrault D, Garel L, et al. Intussusception in children: reliability of US in diagnosis—a prospective study. Radiology 1992; 184:741–744.
9. Lim HK, Bae SH, Lee KH, Seo GS, Yoon GS. Assessment of reducibility of ileocolic intussusception in children: usefulness of color Doppler sonography. Radiology 1994; 191:781–785.
10. del-Pozo G, Gonzales-Spinol J, Gomez-Anson B, et al. Intussusception: trapped peritoneal fluid detected with US-relationship to reducibility and ischemia. Radiology 1996; 201:379-383.
11. Koumanidou C, Vakaki M, Pitsoulakis G, Kakavakis K, Mirilas P. Sonographic detection of lymph nodes in the intussusception of infants and young children: clinical evaluation and hydrostatic reduction. AJR 2002; 178:445–450.
12. Henschke CI, Teele RL. Cholelithiasis in children: recent observations. J Ultrasound Med 1983; 2: 481–484.
13. Georg C, Schwerk WB. Splenic infarction: sonographic patterns, diagnosis, follow-up, and complications. Radiology 1990; 174:803–807.
14. Berrocal T, Prieto C, Pastor I, Gutierrez J, al-Assir I. Sonography of pancreatic disease in infants and children. Radiographics 1995; 15:301–313.

15. Sivit CJ, Siegel MJ, Applegate KE, Newman KD. When appendicitis is suspected in children. Radiographics 2001; 21:247–262.

16. Orr, RK, Porter D, Hartman D. Ultrasonography to evaluate adults for appendicitis: decision making based on meta-analysis and probabilistic reasoning. Acad Emerg Med 1995; 2:644–650.

17. Hernanz-Schulman M, Genieser NB, Ambrosino M. Sonographic diagnosis of intramural duodenal hematoma. J Ultrasound Med 1989; 8:273–276.

18. Watanabe M, Ishii E, Hirowatari Y, et al. Evaluation of abdominal lymphadenopathy in children by ultrasonography. Pediatr Radiol 1997; 27:860–864.

19. Quillin SP, Siegel MJ. Transabdominal Color Doppler ultrasonography of the painful adolescent ovary. J Ultrasound Med 1994; 13:549–555.

20. Stark JE, Siegel MJ. Ovarian torsion in prepubertal and pubertal girls: sonographic findings. AJR Am J Roentgenol 1994; 163:1479–1482.

21. Schmidt RE, Babcock DS, Farrell MK. Use of abdominal and pelvic ultrasound in the diagnosis of chronic abdominal pain. Clin Pediatr (Phila) 1993; 32:147–150.