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Ultrasonographic Evaluation of Nontraumatic Gastrointestinal Emergencies in Children

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Abstract

Acute, nontraumatic gastrointestinal pathologies are commonly encountered in the pediatric emergency department. They often pose a diagnostic dilemma with an assemblage of various etiologies, depending on the age and clinical features. Despite the advent of computed tomography, various issues pertinent to children make ultrasonography (USG) the initial imaging modality of choice in investigating acute gastrointestinal pathologies. This article discusses the ultrasonographic approach to acute gastrointestinal pathologies in children, and how sonography is instrumental in guiding diagnosis and treatment. Characteristic USG findings of common pediatric gastrointestinal emergencies—including acute appendicitis, intussusception, Meckel's diverticulitis, midgut volvulus, bowel perforation, and abdominal tuberculosis—are illustrated in this pictorial review.

Keywords
- ► abdominal tuberculosis
- ► acute appendicitis
- ► acute gastrointestinal pathologies
- ► bowel ultrasound
- ► intussusception
- ► Meckel's diverticulitis
- ► pediatric acute abdomen
- ► ultrasound abdomen

Introduction

Nontraumatic acute abdomen is characterized by sudden onset of previously undiagnosed pain of less than 7 days (usually 48 hours) duration. It is a commonly encountered pediatric emergency, which may or may not be associated with features like abdominal distension, guarding, rigidity, constipation/obstipation, vomiting, and fever. It can occur as a consequence of a wide variety of conditions, ranging from a benign and self-limiting disease to a surgical emergency.

The imaging diagnosis of children with acute abdomen is often challenging due to their inability to give reliable history, nonspecific symptoms, atypical clinical presentations, varying differentials depending on age, and certain extra-abdominal causes (diseases of spine, chest) which may also present as acute abdomen.

Ultrasonography (USG) is extremely useful as an initial and often only imaging modality required for investigating a child with acute abdomen. There is no risk of ionizing radiation, need for sedation, or intravenous contrast. It can reliably aid in formulating the management plan by determining whether it is a surgically or medically treatable disease, detecting possible complications, and diagnosing the exact nature of the pathology in the majority of cases.

Gastrointestinal (GI) pathologies, including acute appendicitis, intussusception, Meckel's diverticulitis, midgut volvulus, bowel perforation, and abdominal tuberculosis (TB), are common culprits in a large number of children with acute

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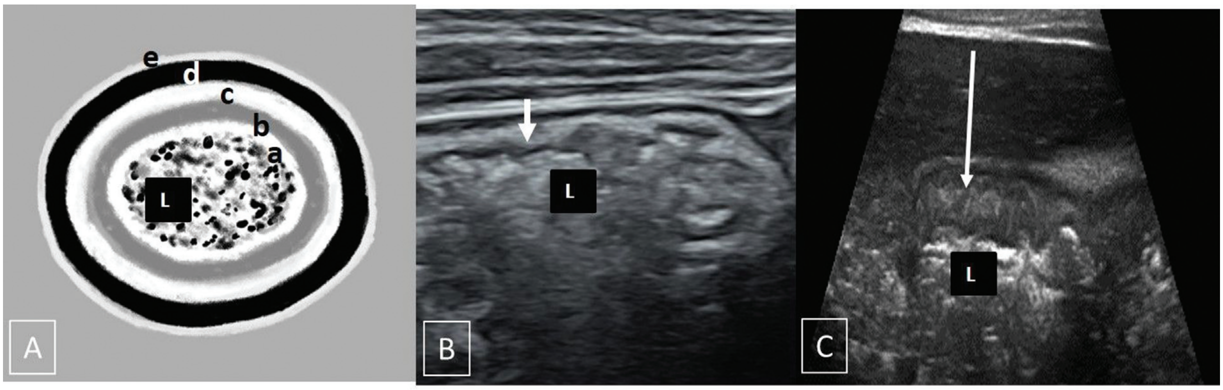

Fig. 1 (**A**) Illustration of gut signature seen as alternating hyper- and hypoechoic lines on ultrasonography (USG) with five layers of the bowel wall: (a) mucosa, (b) muscularis mucosae, (c) submucosa, (d) muscularis propria, and (e) serosa. (**B**) High-frequency USG image of the cecum with normal wall (arrow) showing gut signature. (**C**) Hepatic flexure of colon showing thickened submucosa (white arrow), with maintained wall stratification, in a case of infective colitis. (L) bowel lumen.

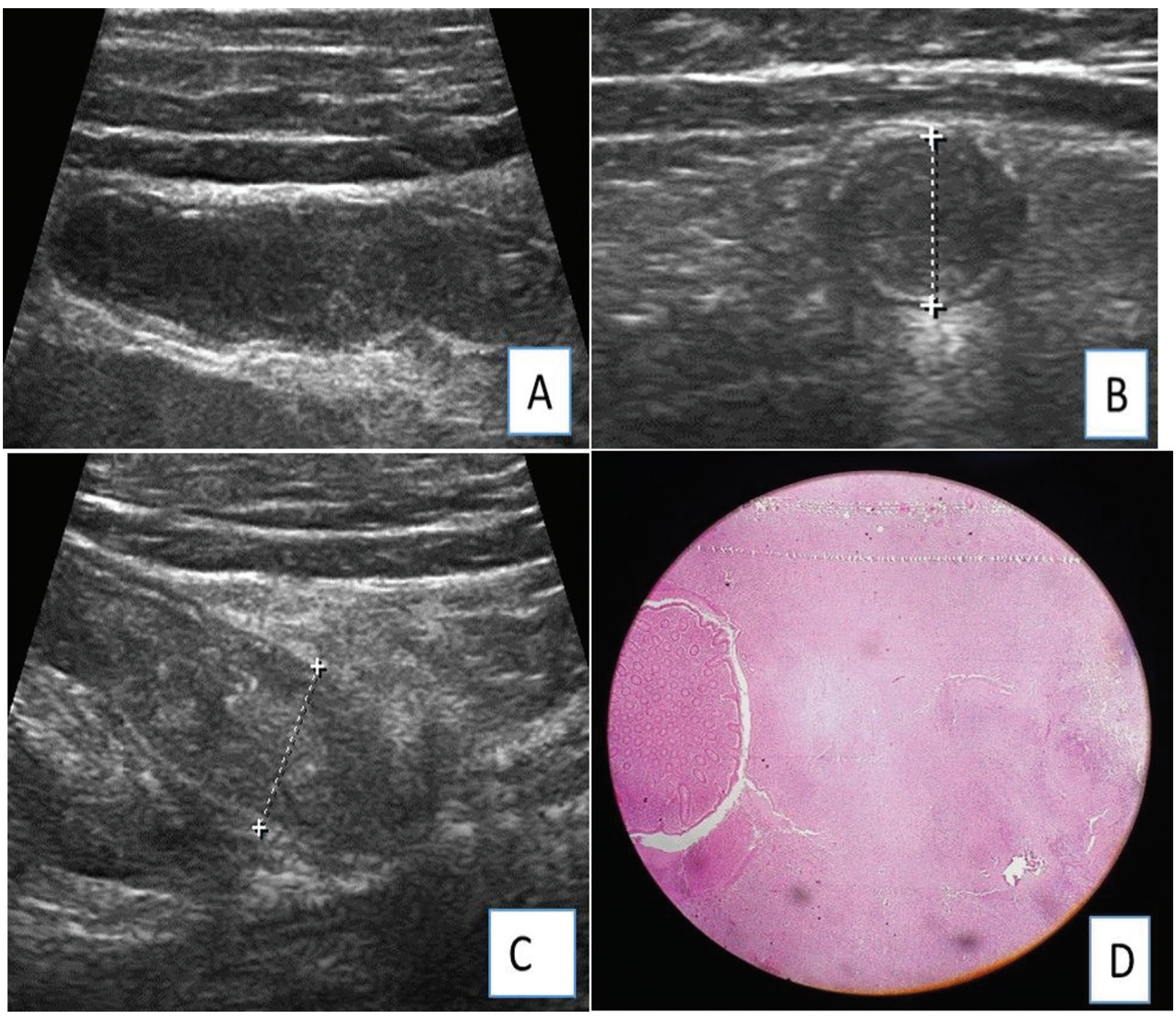

Fig. 2 A 16-year-male with pain in the abdomen, tenderness, and guarding in the right lower abdomen. (**A**) Ultrasound shows dilated appendix with thin and maintained submucosa (arrow). No periappendiceal fluid seen. (**B**, **C**) Measurement of maximal outer wall to wall diameter (11.4 mm) in transverse and longitudinal sections. (**D**) Histopathology of the excised appendix showed inflammatory cell infiltrate with no evidence of ischemia, consistent with uncomplicated appendicitis.

abdominal pain. USG evaluation of these is an essential skill set for all practicing radiologists. In this article, we discuss the proper USG technique for the evaluation of the GI tract, and illustrate characteristic sonographic appearances of various acute GI pathologies in children.

Ultrasonography: Imaging Technique and Anatomy

The ultrasonographic examination is usually performed in the supine position without any prior preparation. After assessment of solid viscera using low-frequency transducers, high-resolution linear probes (12–15 MHz) are used for the assessment of the GI tract. As a routine, bilateral costophrenic angles and basal lung should also be evaluated, as basal consolidation or effusion may sometimes present as acute abdomen.

Bowel is evaluated using the graded-compression method first described by Puylaert et al.[1] This improves visualization of the region of interest by displacing interposing bowel air and fat. Color Doppler flow imaging (CDFI) can be useful to detect hypervascularity (seen in inflammation) or reduced/absent vascularity (ischemia) in the bowel wall.

In children, unique factors like smaller body size and less body fat enhance the diagnostic utility of USG. Targeted evaluation by correlating with the point of maximal probe tenderness, or the site of maximal pain if the patient is able to localize symptoms, can further increase the diagnostic yield. USG can be performed in any imaging plane, which is helpful when evaluating structures like pylorus and appendix, which are not fixed in their orientation. Oblique positioning of the child may sometimes be helpful in the evaluation of suspected appendicitis or hypertrophic pyloric stenosis.

From the esophagus to the rectum, the entire GI tract shows a typical multilamellated appearance on USG, which helps to distinguish the bowel from other structures. This is known as the “gut signature” due its stratified histology.

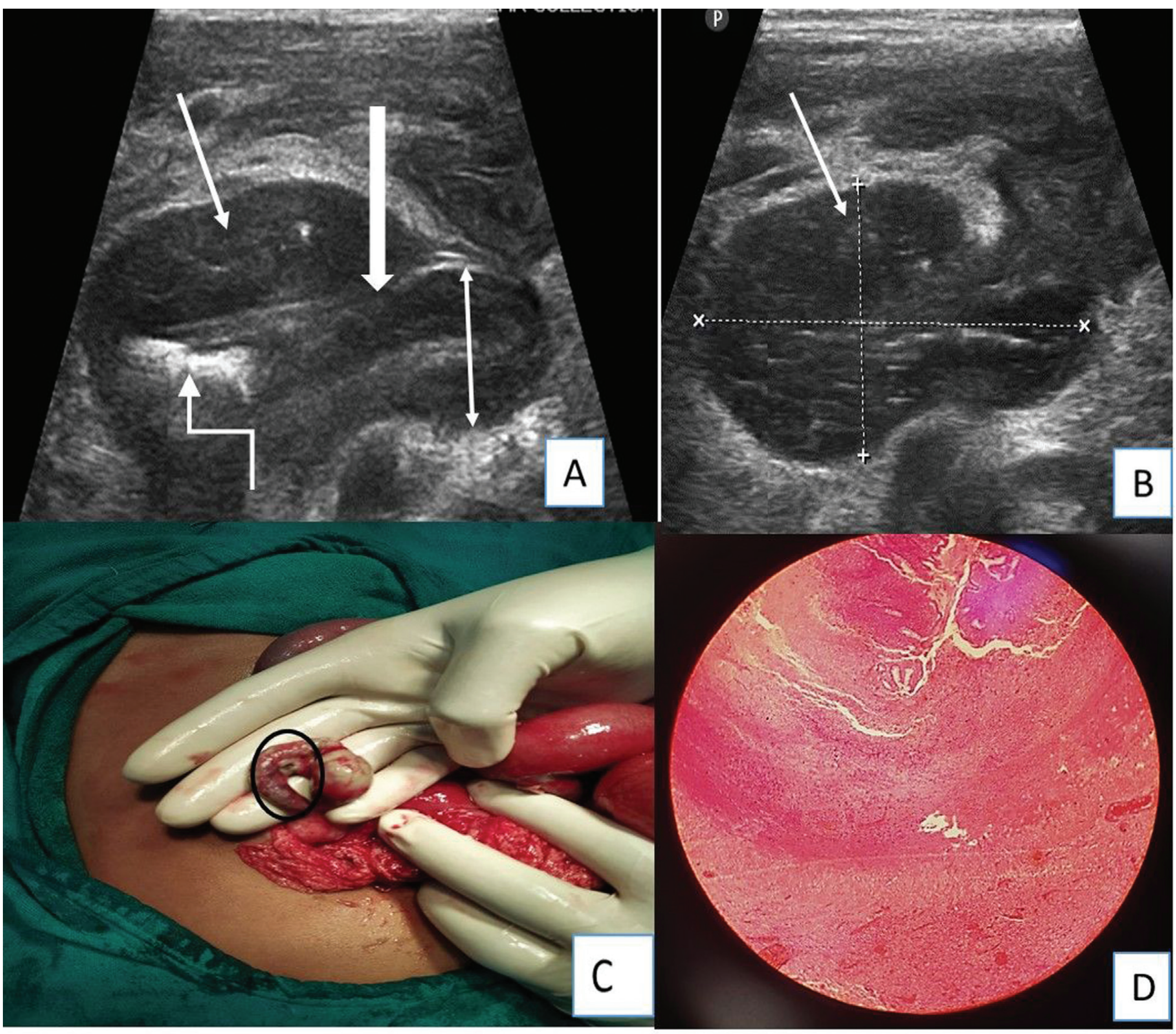

Fig. 3 A 4-year-old male with complicated acute appendicitis. (**A**, **B**) Ultrasonography (USG) shows dilated appendix with loss of wall stratification and a focal wall defect (thick arrow) in the appendiceal body (double-headed arrow), with periappendiceal collection (thin arrow) and appendicolith at the base (bent arrow). (**C**) Intraoperative findings confirmed appendiceal perforation (circle). (**D**) Histopathology demonstrated transmural inflammatory cell infiltrate in the appendiceal wall with gangrenous changes.

Any disruption of this normal stratification, or presence of wall thickening, aids in identifying the site of pathology (►**Fig. 1**).

Mesenteric and omental fat are normally inconspicuous, and when diseased, are visualized on USG as increased echogenicity of fat secondary to edema/infiltration. This extraluminal finding should prompt detailed evaluation of the associated bowel.[2]

Real-time imaging is a unique strength of USG over other imaging modalities. The following dynamic features should be evaluated in GI pathologies:

- Peristalsis: Diminished peristalsis is a nonspecific indicator of small bowel pathology. However, hyperperistalsis may be seen in early or partial small bowel obstruction (SBO).
- Compression: Normal bowel can be compressed and displaced by transducer pressure. Lack of compressibility or tenderness on compression signifies active inflammation.
- Color and power Doppler imaging of the bowel wall provide supplementary information. Increased vascularity denotes active inflammation, whereas diminished vascularity is a specific, though not sensitive, sign of ischemia.[3]
- Inguinal and umbilical hernias may present with acute abdomen in children due to obstruction or strangulation. Direct observation during Valsalva maneuver while the child cries/coughs is helpful in better depiction of a hernial sac or abdominal wall defect, and also helps assess reducibility.

Acute Appendicitis

Acute appendicitis is a common surgical emergency which can occur at any age, but has higher incidence in children between 5 and 15 years of age. Nonspecific clinical presentation may lead to a delay in diagnosis and serious complications like perforation peritonitis, bowel obstruction, or sepsis.

USG Imaging of the Appendix

The appendix develops from midgut. Though its base is fixed, its tip can be found in any position relative to the cecum. Key

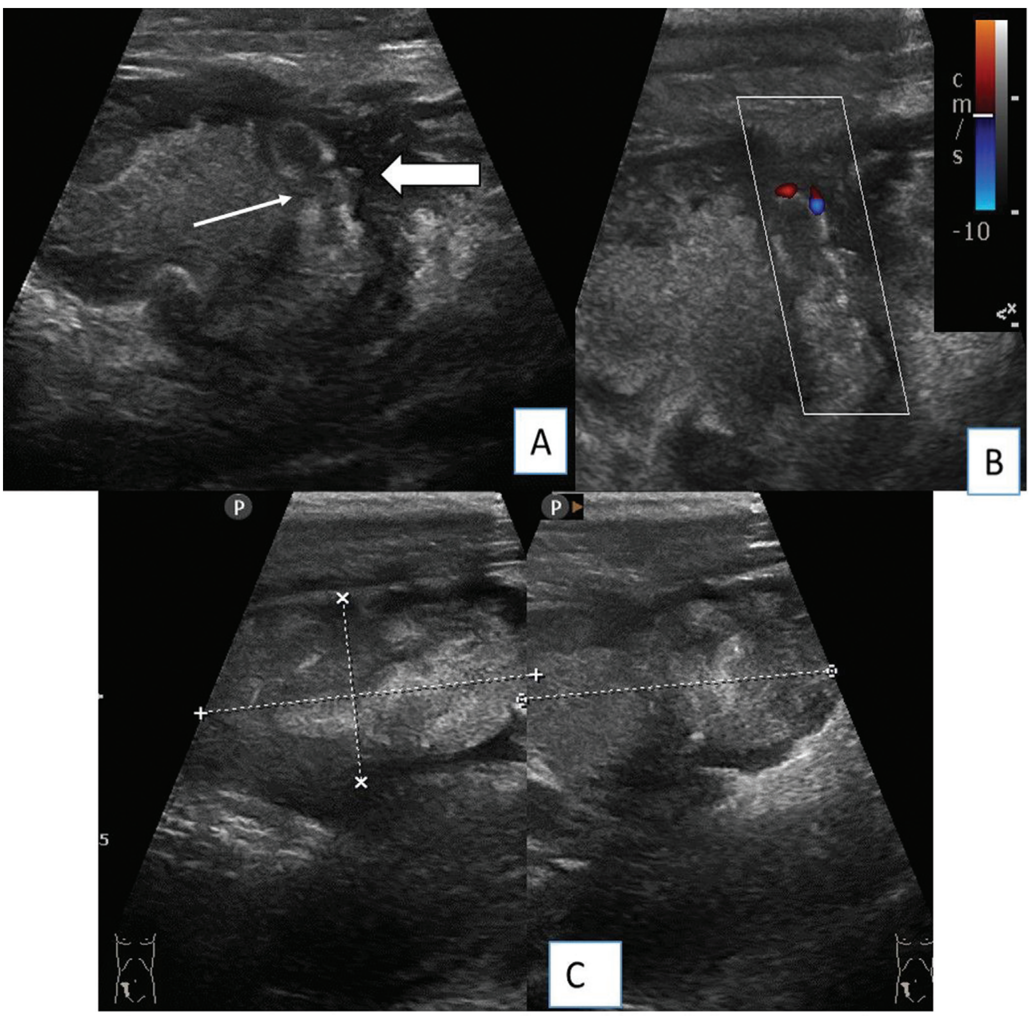

Fig. 4 Appendicular phlegmon in a 9-year-old female. (**A**) Ultrasonography (USG) shows dilated appendix with areas of submucosal breach and periappendicular phlegmon. (**B**) Color Doppler shows increased vascularity in appendiceal wall. (**C**) Appendicular phlegmon volume was approximately 26 mL.

anatomic landmarks that must be visualized for localizing the appendix include the cecum, external iliac vessels, and psoas muscle. Using a high-frequency linear transducer, scanning should begin at the edge of the right lobe of the liver, moving downward along the ascending colon toward the right iliac fossa to locate the cecum. Appendix is recognized as an aperistaltic structure containing gas/fluid, arising from the posteromedial aspect of the cecum, about a few centimeters inferior to the ileocecal valve. The normal appendix can be seen often on USG in children, though not in all individuals.

Inability to visualize the inflamed appendix can occur due to extensive bowel gas or severe guarding by the patient. Following a proper USG technique using graded compression is essential in reducing false-negative examinations. USG signs of appendicitis can be grouped into two categories—appendiceal and periappendiceal findings.

Appendiceal features include maximum outer wall to wall diameter of ≥ 7 mm,[4] single wall thickness of ≥ 3 mm, and noncompressibility.[4,5] Appendicoliths may be associated with higher perforation risk.[6] Normally, flow may not be visualized in appendix on CDFI, hence demonstration of wall hyperemia may be a valuable aid in borderline cases.[7]

Periappendiceal features include free fluid in the periappendiceal region, increased echogenicity of the periappendiceal fat, adjacent lymphadenopathy, and secondary SBO.

USG can not only help in diagnosing acute appendicitis, but can also predict the likelihood of complicated appendicitis, which helps in management decisions.

Uncomplicated appendicitis: A thin and smooth uninterrupted layer of the submucosa is seen in early (uncomplicated) appendicitis (►**Fig. 2**). Progressively, the submucosal layer appears thickened but intact, with hyperemia on Doppler signifying transmural spread of suppurative infection.[8,9]

Complicated appendicitis: Furthermore, a focal or global loss of the echogenic submucosal layer that is avascular on color Doppler heralds gangrenous change. This area can perforate and a liquefied collection may form (►**Fig. 3**)—either intraperitoneal or retroperitoneal (right paracolic gutter). Alternatively, an indurated mass-like inflammatory mass called phlegmon (►**Fig. 4**) may develop formed by the surrounding soft tissues, with nonvisualization of the appendix separately.[8,9]

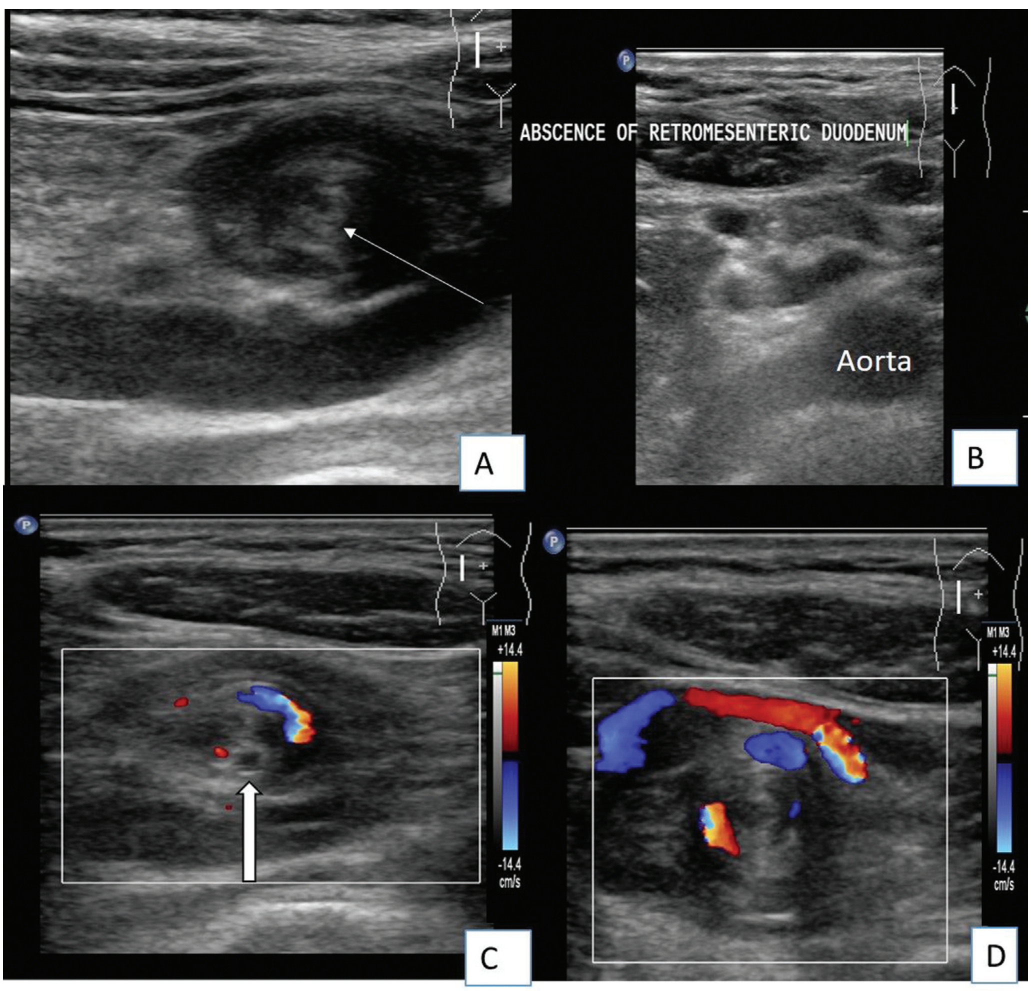

Fig. 5 Malrotation with midgut volvulus in a 10-year-old female who presented with bilious vomiting and acute pain abdomen. (**A**, **B**) Gray scale high-frequency ultrasonography (USG) images demonstrate whirlpool sign (thin arrow) and absence of retromesenteric duodenum crossing the midline. (**C**, **D**) Swirling of vessels is well depicted on color Doppler. The superior mesenteric artery (thick arrow) was seen at the center of the whirlpool.

Diagnostic Pitfalls in Ultrasound Imaging of Acute Appendicitis

(1) Appendicitis confined to the appendiceal tip can result in a false-negative USG. Hence, tracing the entire length of the appendix is essential.
(2) Retrocecal appendicitis is difficult to visualize by the standard anterior USG approach. Sagittal scanning using a lateral flank approach, with the child in supine or right anterior oblique position, permits visualization posterior to the cecum.
(3) Appendiceal inflammation secondary to surrounding inflammation like Crohn's disease or tubo-ovarian abscesses can mimic acute appendicitis.

Midgut Volvulus with Malrotation

Malrotation is a congenital cause of upper GI obstruction in children. Although it can present clinically at any age, majority of the affected individuals become symptomatic before 1 year, and often present with midgut volvulus, as a surgical emergency. The investigation of choice for suspected malrotation is an upper GI contrast study.[10] However, its interpretation can be challenging at times. The diagnosis of malrotation on an upper GI study is based on the demonstration of abnormal position of the duodenojejunal flexure, which should be assessed in a true frontal projection and during the first-pass of contrast during a fluoroscopic examination. This may be challenging in a small infant. The location of proximal jejunal loops in a child with malrotation may sometimes be normal, which may result in an equivocal or false-negative examination. Also, a fluoroscopically performed contrast study has disadvantages like radiation exposure and the need for contrast administration. As USG is readily available, free of radiation, and requires no patient preparation or sedation, it can be used as the initial imaging modality for suspected cases of malrotation. It is helpful in determining the relative position of the superior mesenteric artery (SMA) and vein (SMV), and the position of the third part of the duodenum.

Imaging features of midgut volvulus on sonography include the intestinal "whirlpool sign," which is well demonstrated on ultrasound and Doppler. This is caused by the twisting of the bowel loops along with the mesenteric vessels. Other features

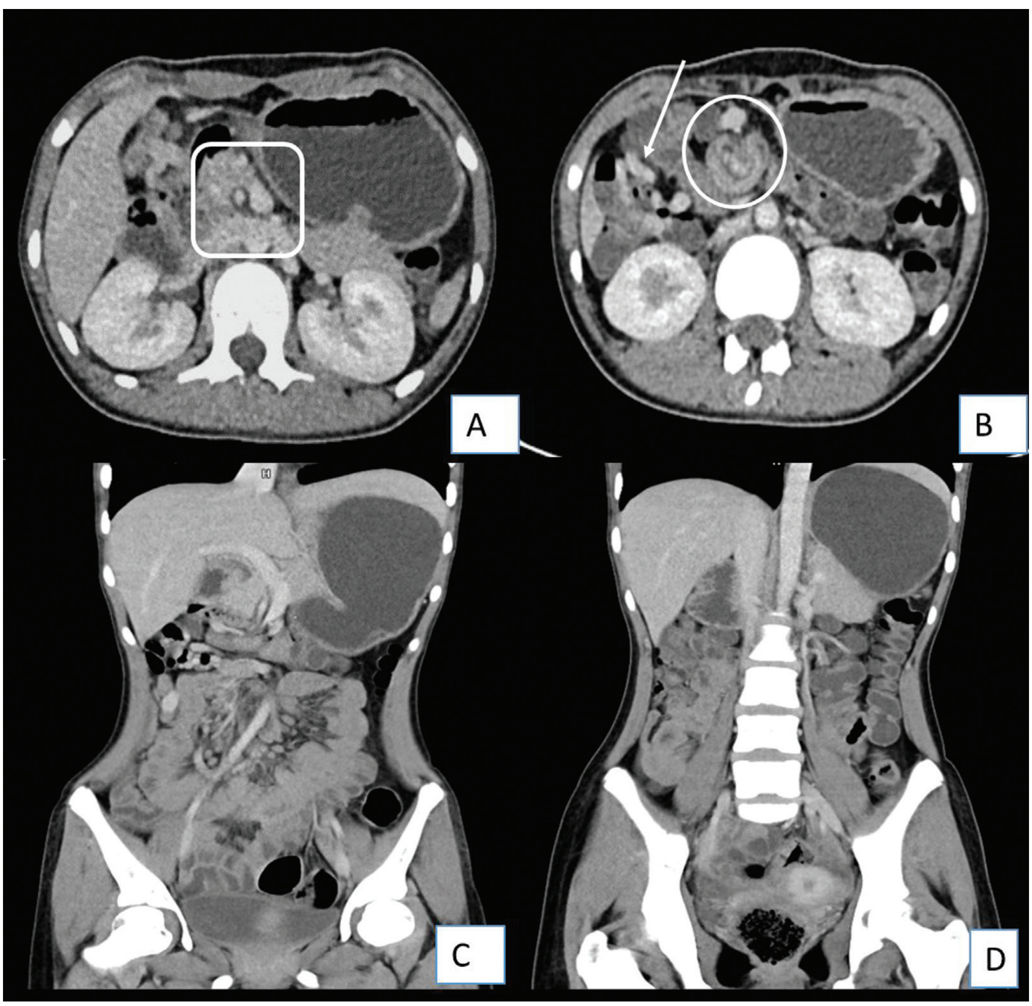

Fig. 6 Computed tomography (CT) of the same patient as ►**Fig. 5**. (**A**) Axial contrast-enhanced CT (CECT) images demonstrating inverse relationship of superior mesenteric artery-superior mesenteric vein (SMA-SMV) and absence of duodenum crossing midline. (**B**) Swirling of mesentery and bowel around SMA with dilated surrounding venous collaterals (arrow), likely due to compression of the SMV. (**C**, **D**) Coronal CECT images showing small bowel predominantly on the right and large bowel on the left side of the abdomen.

include nonvisualization of the retromesenteric transverse duodenum and inversion of the SMA and SMV orientation (►**Fig. 5**). Based on the anatomic and embryology principles, if the third part of the duodenum lies retroperitoneally behind the SMA and aorta, this is a safe indicator to exclude malrotation. This sign has been recently confirmed to be both very specific and sensitive for diagnosis of malrotation.[11] If the SMV is not situated to the right of the SMA in the axial plane at the level of the portal vein confluence, this finding is suggestive of intestinal malrotation. However, this inverse relationship may be detected in normal rotation as well, whereas abnormal relationship is not a rule in malrotation.[12]

Computed tomography (CT) may also be useful in equivocal cases, and findings are similar to those seen on USG (►**Fig. 6**).

Intussusception

Intussusception is the "telescoping" of bowel into bowel that commonly occurs in the age group of 6 to 18 months. The intussuscipiens ("receiving" loop) contains the infolded intussusceptum ("donor" loop), along with the attached mesentery between the two limbs, and sometimes may contain pathologic lead points (PLPs) or lymph nodes. In children, 90% of cases occur without lead points ("idiopathic"), occurring secondary to uncoordinated peristalsis of the gut or due to lymphoid hyperplasia.[13] A fraction of cases (approximately 5–6%) are secondary to PLP, the commonly encountered PLPs being Meckel's diverticulum (MD), enteric cyst, polyp, and lymphoma.[14] Majority of intussusceptions are of ileocolic type and found in the right subhepatic region.

USG findings: Various characteristic ultrasound appearances have been described for intussusception in different planes: the "donut" or "target" sign is seen in the transverse plane due to alternating concentric hypoechoic and echogenic layers. Longitudinal images confirm the telescoping, giving a bowel-within-bowel appearance (►**Fig. 7**). When imaged obliquely, the "pseudokidney" sign may be seen, the

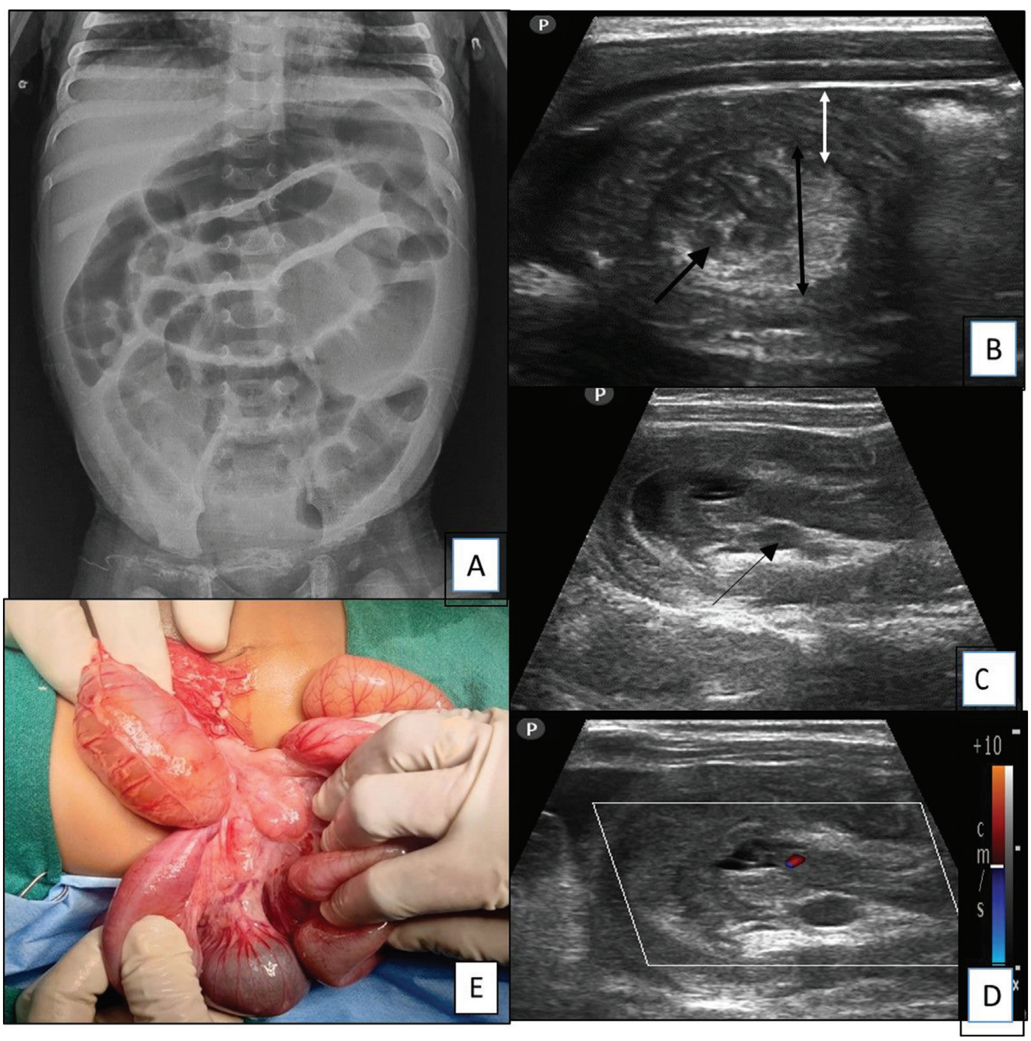

Fig. 7 Ileocolic intussusception in a 13-month-old male who presented with pain abdomen and nonpassage of stools. (**A**) Abdominal radiograph reveals dilated small bowel loops suggestive of small bowel obstruction. (**B**, **C**) Transverse and longitudinal ultrasonography (USG) showing target sign and pseudokidney sign, respectively. Lymph nodes are seen within the intussusception (black arrow in **B** and **C**. Fatty core (black double-headed arrow in **B**) to wall (white double-headed arrow in **B**) index was > 1. (**D**) Longitudinal image showing preserved vascularity within the intussusceptum. (**E**) Surgery confirmed ileocolic intussusception.

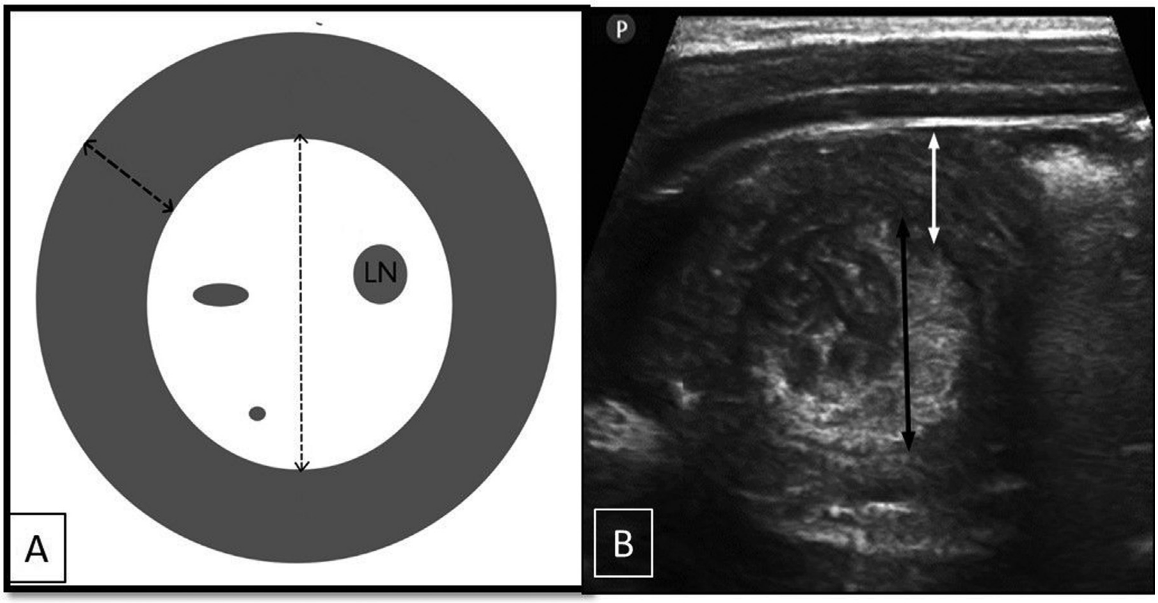

Fig. 8 (**A**) Illustration of core to wall index used to classify intussusception. Echogenic core should be measured at its maximum thickness and divided by the thickness of the hypoechoic wall. (**B**) A case of ileocolic intussusception showing core to wall index > 1.

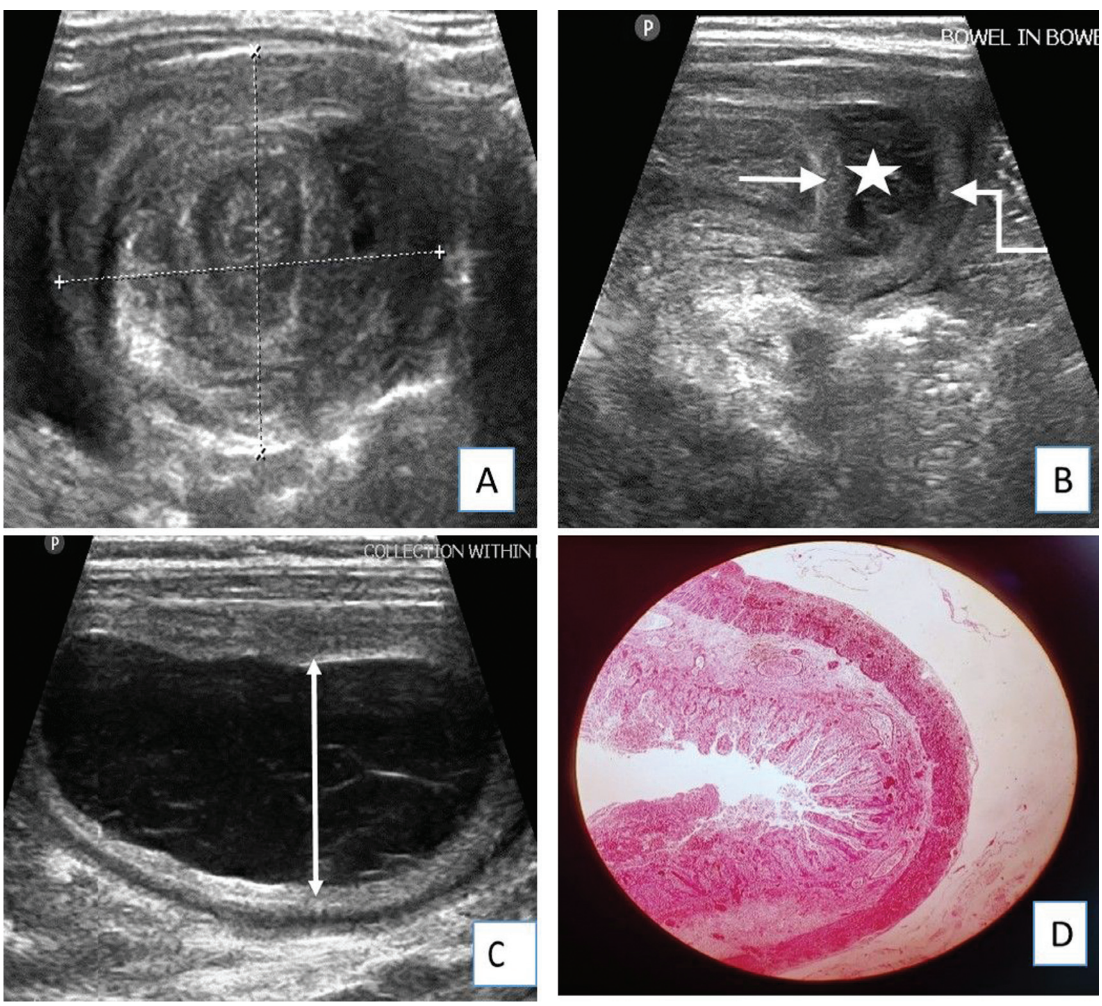

Fig. 9 Intussusception with gangrene. A 12-month-old male presented with pain abdomen and nonpassage of stools/flatus. (**A**) Transverse ultrasonography (USG) image showing target appearance of intussusception. (**B**) Longitudinal section near the tip showing interbowel free fluid (star) between thickened edematous walls of intussusceptum (arrow) and intussuscepiens (bent arrow). (**C**) Septated interloop fluid of depth 15 mm. (**D**) Histopathology of the tip of intussusceptum showed transmural necrosis.

hypoechoic bowel wall resembling the renal cortex, and the echogenic mesentery resembling the central fatty sinus.

Certain ultrasound features can also reliably distinguish the type of intussusception, whether ileocolic or small bowel intussusception:

Core to wall index: Ileocolic intussusceptions always contain a prominent central echogenic core due to ileal mesentery. A small bowel intussusception shows no or a minimal fatty component. A core-to-wall ratio greater than 1.0 is characteristic of ileocolic intussusception, whereas in small bowel intussusceptions the ratio is less than 1 (►**Fig. 8**).[15]

The presence of lymph nodes in the core of intussusception and larger lesion diameter are also characteristic of ileocolic intussusceptions.[15]

USG has a role not only in the diagnosis but also in the management of ileocolic intussusception. Nonsurgical reduction of intussusception in children is safe and effective, and is the first-line treatment. This may be performed under fluoroscopy or USG guidance, and the procedure can be performed using pneumatic enema (air reduction) or hydrostatic enema with saline or water-soluble contrast. Whatever combination is used, the basic principle remains the same—introduction of pressurized liquid/air into the colon pushes and reduces the intussusception, through the length of the colon and then the ileocecal valve. Imaging guidance is used to confirm completeness of the reduction.

USG can also help to predict failure of reduction and detect the need for surgical intervention for intussusception. Proximal bowel obstruction, ascites, and presence of interloop free fluid (between intussusceptum and intussuscepiens) of depth > 9 mm is correlated with increased risk of lead tip necrosis and failure of reduction[16] (►**Fig. 9**). In case of small bowel intussusception, length greater than 3.5 cm is a strong independent predictor of the need for surgical intervention.[17]

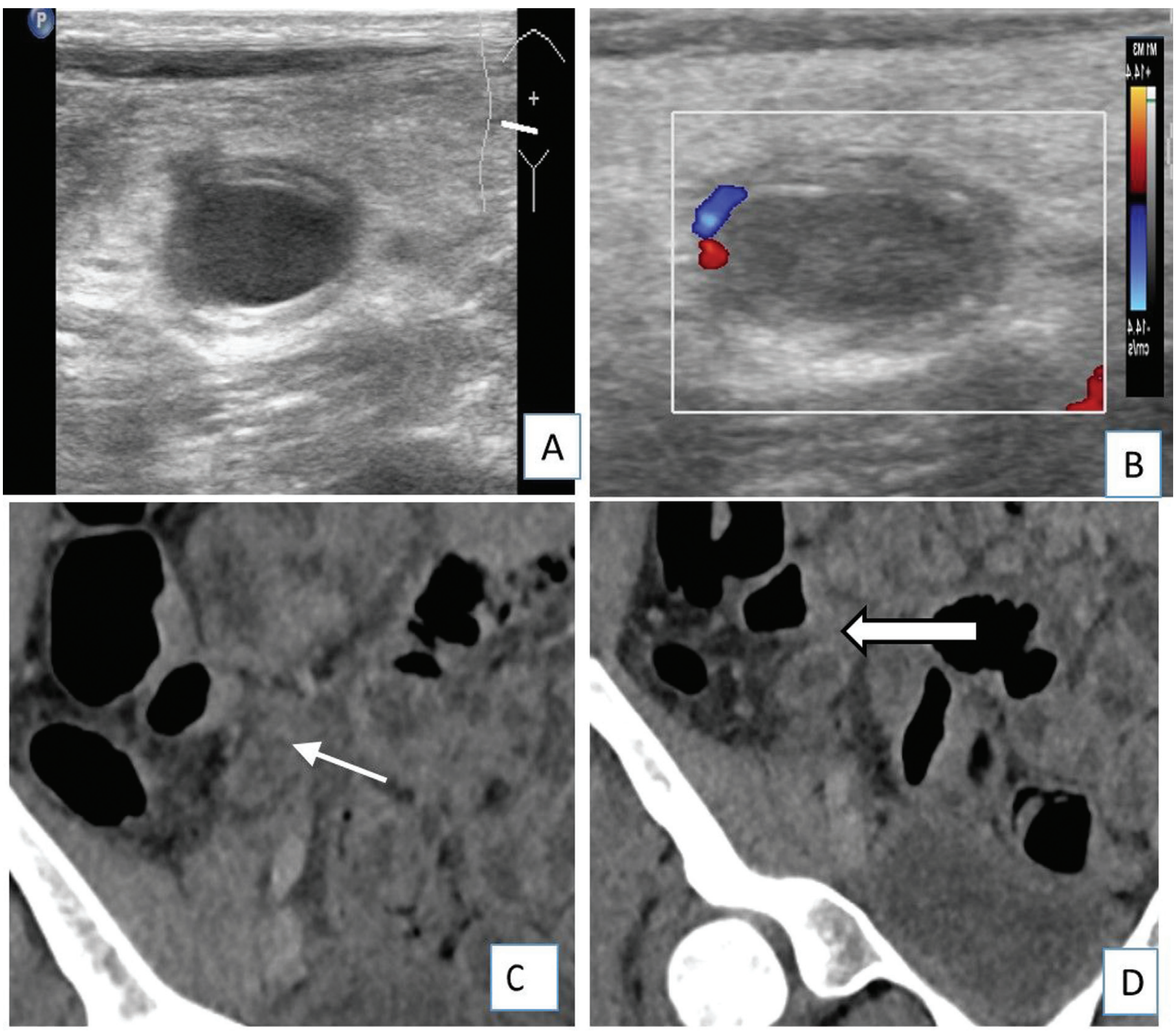

Fig. 10 Meckel's diverticulitis. A 14-year-old male presented with pain and tenderness in the right iliac fossa (RIF). (**A**) Ultrasonography (USG) images demonstrate a fluid-filled cystic structure in the RIF with gut signature in the wall and echogenic surrounding fat. (**B**) Doppler demonstrates color flow in the wall. (**C, D**) Serial coronal contrast-enhanced computed tomography (CECT) images demonstrating a fluid-filled tubular structure with enhancing walls and surrounding fat stranding; communicating with terminal ileal loops (thick arrow in **D**).

Meckel's Diverticulitis

MD is a congenital true diverticulum that occurs on the antimesenteric ileal border due to failure of vitelline (omphalomesenteric) duct obliteration. It can have varied clinical presentations such as hematochezia, lead point for intussusception, diverticulitis, and intestinal obstruction. MD may be lined by ectopic gastric mucosa, and acid secretion from this ectopic mucosa can result in diverticulitis. Inflammation may also occur secondary to obstruction. Meckel's diverticulitis can mimic appendicitis both clinically and on sonography. As the clinical differential diagnosis is broad, Meckel's diverticulitis is often not suspected clinically.

In children, technetium-99m pertechnetate scintigraphy is a highly accurate tool for diagnosis of an inflamed MD as pertechnetate is taken up by the mucin-secreting cells of the ectopic gastric mucosa.[18] In children, it shows a high sensitivity of 85 to 90%, as compared to approximately 60% sensitivity in adults. False-positive results may occur due to ectopic gastric mucosa elsewhere in the bowel, duplication cyst, or inflammatory bowel disease. Delayed intestinal activity of normal bowel can sometimes mask the uptake in the MD and give a false-negative result.

USG is useful in symptomatic patients. On USG, MD appears as a cystic/tubular structure, with wall exhibiting the gut signature (►**Fig. 10**). Inflammation of a tubular diverticulum may be difficult to differentiate on USG from an inflamed appendix. The entire length of the structure should be carefully traced to determine whether the structure arises from the base of the cecum (appendix), or from the small bowel (MD). CT may be helpful in equivocal cases, by better delineation of the anatomy. Visualization of a

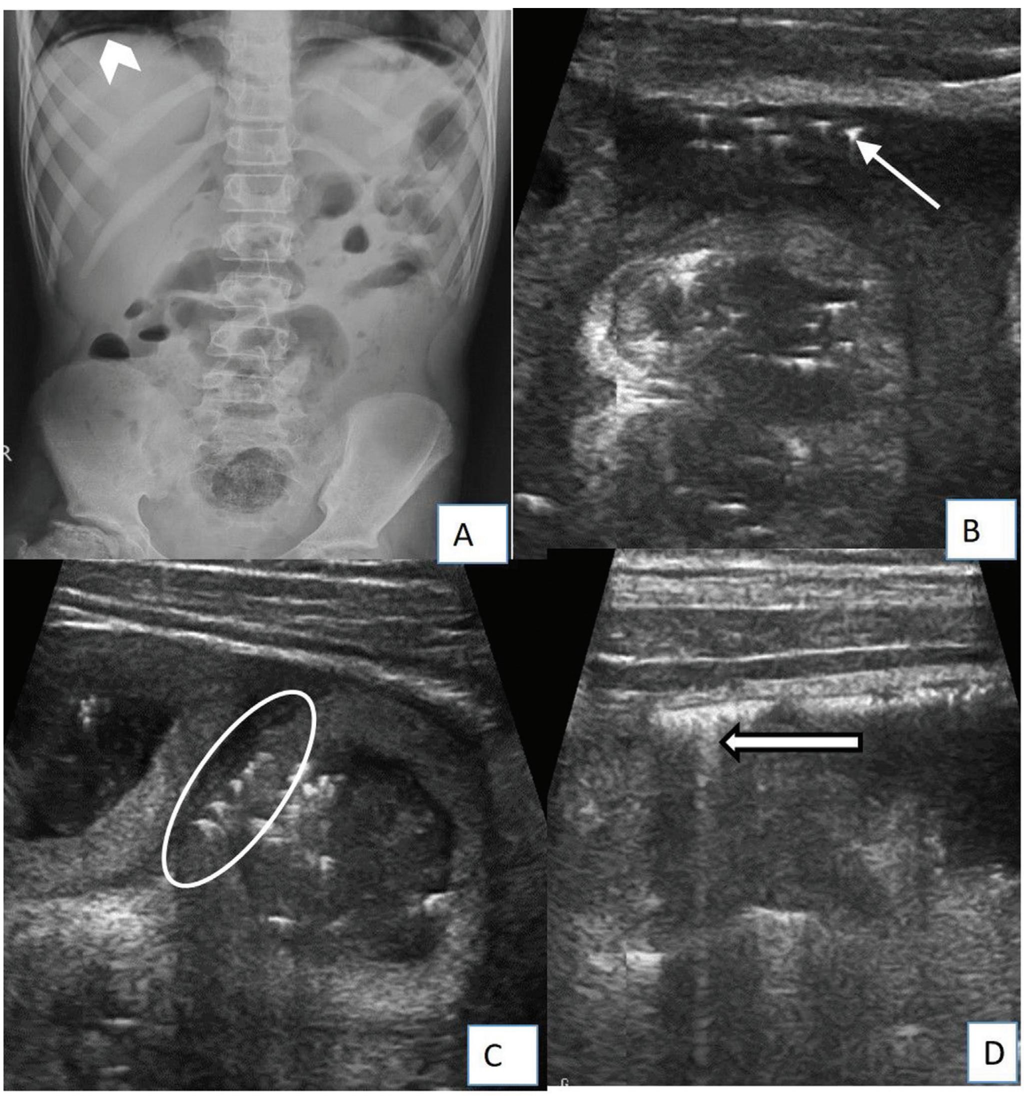

Fig. 11 Pneumoperitoneum due to bowel perforation. (**A**) Erect abdominal radiograph in a 7-year-old male demonstrating free air under diaphragm (arrowhead) with no abnormal air fluid levels. (**B**) High-frequency ultrasonography (USG) images in the right iliac fossa (RIF) showing ascites with echoes and echogenic foci showing comet-tail artifacts, suggesting free intraperitoneal air (arrow). (**C**) USG images showing small bowel loops with thickened wall and intramural air foci (oval). (**D**) USG image of a different patient with hollow viscus perforation showing echogenic peritoneum with posterior reverberation artifact—peritoneal stripe sign (thick arrow).

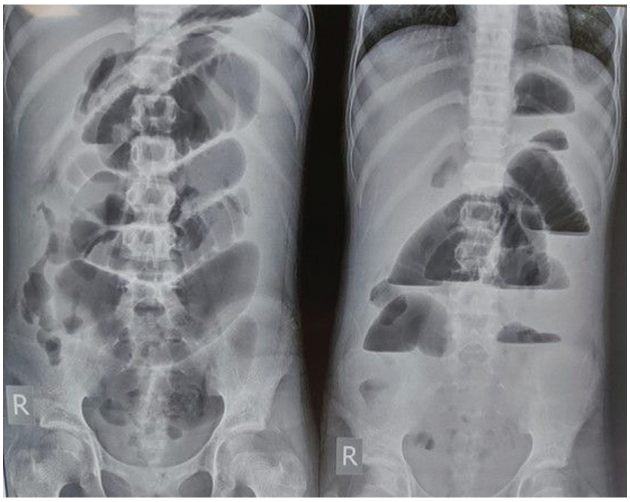

Fig. 12 A 13-year-old female presented with abdominal pain and nonpassage of stools. Supine and erect abdominal radiographs showing dilated jejunal and ileal loops in the central abdomen with multiple air-fluid levels, diagnostic for small bowel obstruction. No free air noted.

normal appendix separately on CT can help in clinching the diagnosis. Intestinal duplication cyst can also have an imaging appearance similar to a rounded/cystic MD, but a MD usually has a more irregular wall than a duplication cyst.[19]

Intestinal Perforation and Pneumoperitoneum

Traditionally, upright posteroanterior chest and left lateral decubitus radiographs (in unstable patients) are used for the imaging evaluation of suspected pneumoperitoneum. However, USG can be used in cases with suspected perforation, even when radiographs do not reveal pneumoperitoneum.

On USG, intraperitoneal free air is seen as multiple, parallel, linear echogenic lines with ring-down artifacts ("peritoneal stripe" sign) or smaller echogenic foci with comet-tail artifacts (►**Fig. 11**). This is observed in the nondependent regions, most commonly over the right hypochondrium or epigastrium wall due to good contrast between the artifact and the hepatic parenchyma.[20]

Some pitfalls like overlying rib shadows, ring-down artifacts from the basal lung/intraluminal bowel gas, and colonic gas interposition anterior to the liver can be misinterpreted as pneumoperitoneum on USG. Displacement of the interference echo pattern with change in patient position from supine to left lateral decubitus is typically a sign of free intraperitoneal air and not observed with intraluminal air or alveolar air.[20]

Small Bowel Obstruction

SBO in young children may result from adhesions, which are a consequence of previous abdominal surgery. The incidence of adhesive SBO in children varies from 1 to 13%, and depends on the type of surgery. Risk factors for SBO development include undergoing an emergency surgery, history of stoma, postoperative infections, and multiple surgeries. In children less than 3 years, surgery for intestinal atresias, necrotizing enterocolitis, and gastroschisis are high risk for subsequent development of SBO. [21]

USG is not commonly used for evaluating SBO because obstructed gas-filled bowel loops lead to nondiagnostic sonograms in a large majority of cases. Also, adhesions, which are a common cause of mechanical SBO, cannot not detected by ultrasound. Despite these limitations, in the emergency setting USG can provide valuable information, especially in conjunction with abdominal radiographs (►**Fig. 12**), as it can demonstrate the following[22]:

- Luminal caliber of small bowel loops of > 3 cm indicates presence of obstruction. The cause of obstruction can be diagnosed in some instances—like bezoars, intussusception, inguinal/umbilical hernia, and abdominal TB (►**Fig. 13**).
- Peristalsis: hyperperistalsis is seen as a to-and-fro or whirling motion of the bowel contents.

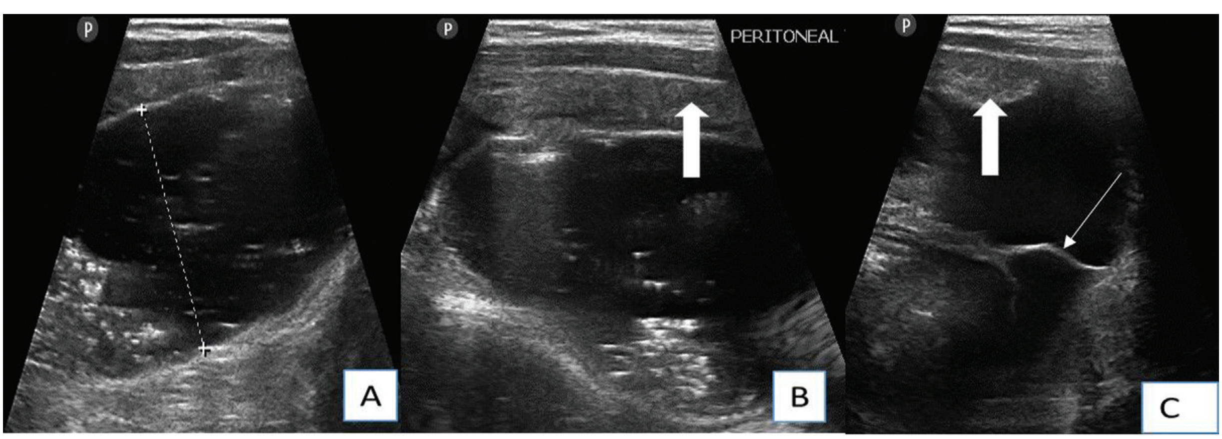

Fig. 13 Ultrasonography (USG) images of the same patient as ►**Fig. 12** show dilated ileal loops with caliber 3.6 cm (**A**), peritoneal thickening (thick arrows in **B** and **C**), and ascites with fine septations (thin arrow in **D**). Tubercular etiology was suspected based on these findings, and patient started on antitubercular therapy.

- Level of obstruction: can be partly determined by means of location of the dilated bowel loops.
- Associated complications: ascites, aperistalsis, and wall thickening (> 3 mm) in a fluid-filled distended bowel segment may suggest onset of bowel ischemia.

Abdominal Tuberculosis

Abdominal TB continues to be a significant problem in developing countries, including India. It can show intestinal, peritoneal, lymph nodal, or visceral organ involvement, often with overlapping features. Intestinal TB is seen predominantly in adults, while peritoneal and lymph node disease is predominant in children.[23]

Confirmation of the diagnosis of TB is ideally microbiological or on histopathology. However, in endemic areas with high disease burden, characteristic imaging findings with a high index of clinical suspicion and other ancillary laboratory evidence are sufficient for a probable diagnosis.

Intestinal TB: The most commonly involved site is the ileum and ileocecal junction (ICJ), although it can involve any part of the GI tract. USG usually reveals concentric bowel wall thickening. Matted masses constituted by thickened bowel loops, ascites, and regional lymph nodes may also be observed.[24]

Lymph nodal TB: Mesenteric root, porta hepatis, and peripancreatic lymph nodes draining the jejunum, ileum, ICJ, and ascending colon are commonly involved. There are

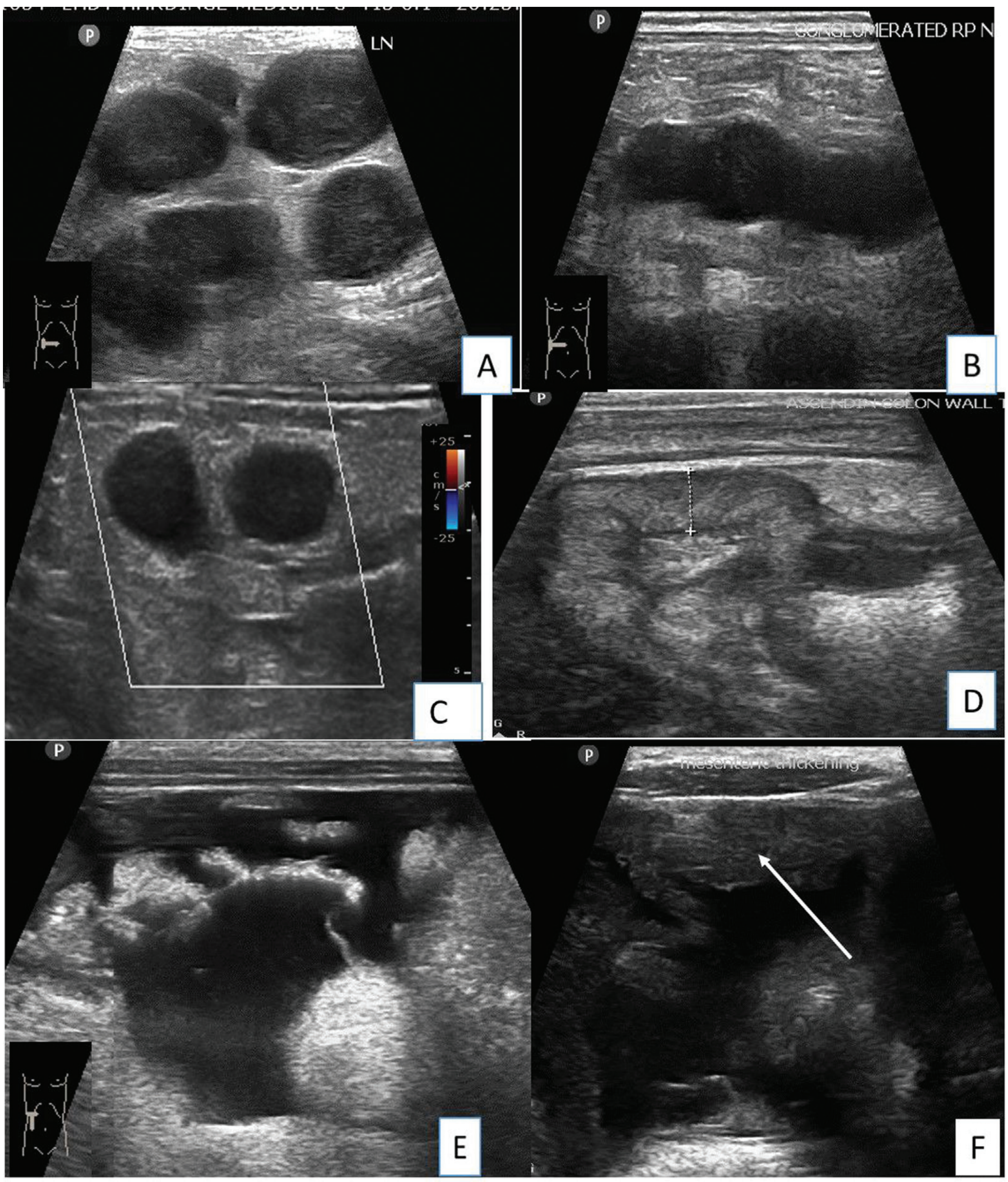

Fig. 14 Spectrum of ultrasonography (USG) findings in children with abdominal tuberculosis presenting as acute abdomen. USG images (from different patients) showing (**A**) cluster of enlarged hypoechoic mesenteric lymph nodes, (**B**) conglomerated lymph nodes, and (**C**) lymph nodes without any internal or peripheral vascularity on color Doppler. (**D**) Circumferential bowel wall thickening involving terminal ileum, (**E**) ascites with fine septations and internal echoes, and (**F**) sheet-like peritoneal thickening (arrow) with ascites.

varied patterns of adenopathy, ranging from discrete enlarged rounded hypoechoic nodes to matted large conglomerate masses with or without calcification.[23,24]

Peritoneal TB: Free or loculated ascites is seen in most cases demonstratable by both USG and CT. However, USG scores over CT in imaging to detect small amount of ascites and to visualize fine, mobile strands of fibrin and debris, characteristic of TB.[24]

Ultrasound can reveal one or more of these findings in variable combinations (►**Fig. 14**).

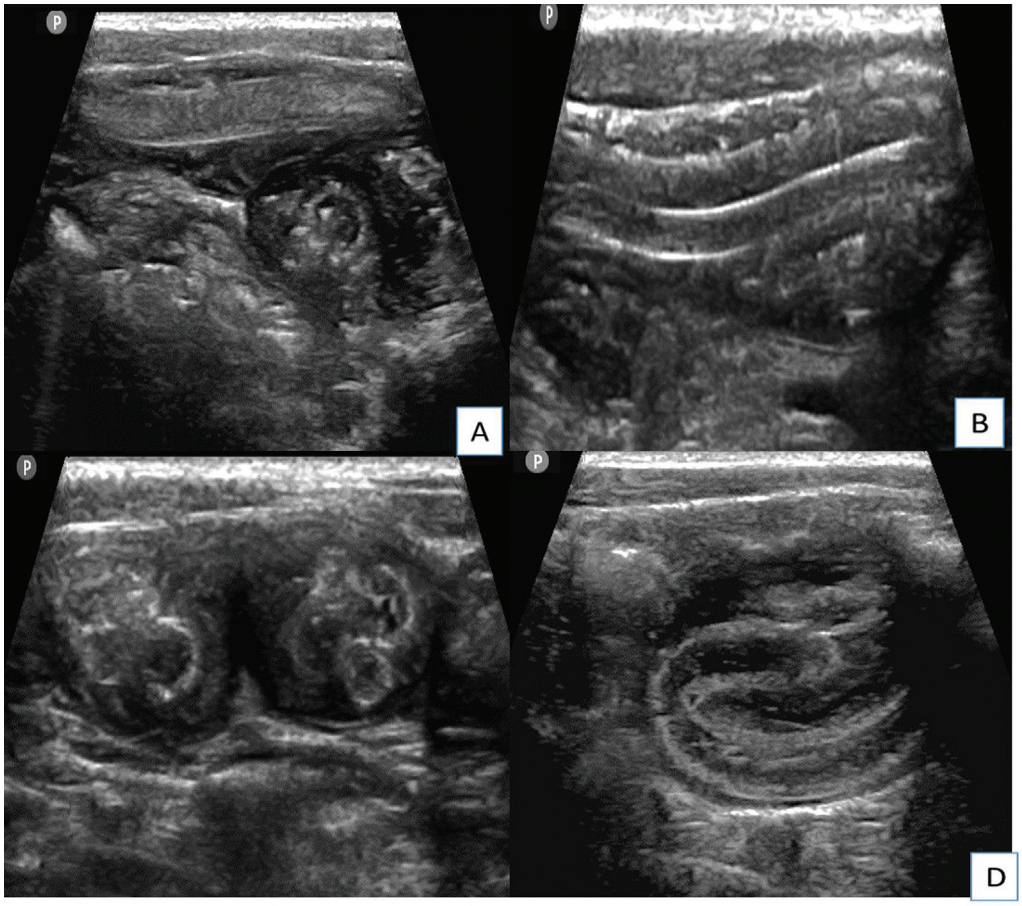

Fig. 15 Bowel ascariasis in a 9-year-old male with diffuse pain abdomen. High-frequency ultrasonography (USG) images (**A**–**D**) in the right iliac fossa (RIF) demonstrating intraluminal hypoechoic tubular structures with echogenic walls within the ileal loops, consistent with worm infestation. No clinical or USG features of bowel obstruction were present.

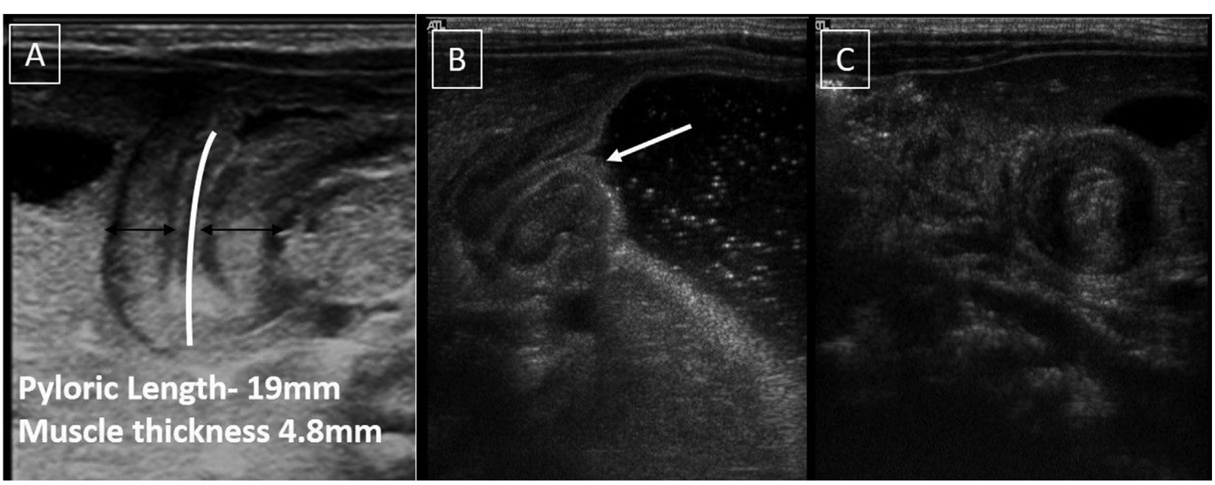

Fig. 16 Case of hypertrophic pyloric stenosis. (**A**, **B**) Oblique ultrasonography (USG) images reveal elongation of the pylorus (white arc) with increased muscle thickness (black double-headed arrows) projecting into the pylorus (cervix sign), with prolapsed mucosa giving the antral nipple sign (white arrow in **B**). (**C**) Transverse USG image showing target appearance due to thickened pyloric muscle.

Ascariasis

Roundworm infestation caused by *Ascaris lumbricoides* is one of the most common helminthic diseases worldwide. It can present with nonspecific pain abdomen and can sometimes lead to acute or subacute intestinal obstruction. *Ascaris* worms are mobile and appear as tubular intraluminal structures within the bowel loops with echogenic walls and central hypoechogenicity, corresponding to the alimentary canal of the worm. In the transverse section, worms have a doughnut-like appearance with an echogenic rim (►**Fig. 15**).[25]

Hypertrophic Pyloric Stenosis

This entity usually presents at 2 weeks to 3 months of age and has a male preponderance. Hypertrophy of circular muscle of the pylorus results in gastric outlet obstruction and projectile nonbilious vomiting. USG is the imaging modality of choice. Increased thickness of the pylorus muscle of > 3 mm is diagnostic (2–3 mm is equivocal). The pylorus is elongated and measures > 15 mm in length (►**Fig. 16**). It needs to be differentiated from pylorospasm wherein the muscle is seen to open up on repeat scan, performed after 10 minutes with patient's right side down.[26]

The visualization of the prolapsed mucosa and hypertrophied elongated pylorus muscle into the antrum are termed as the *antral nipple* and *cervix sign*, respectively.[27]

Bezoar

A bezoar is an accumulation of undigestible material within the GI tract. Phytobezoars comprise of fruit and vegetable matter, while trichobezoars are formed by impaction of ingested hair along with mucus and food, usually in adolescent females. They resist digestion, escape peristalsis, and get

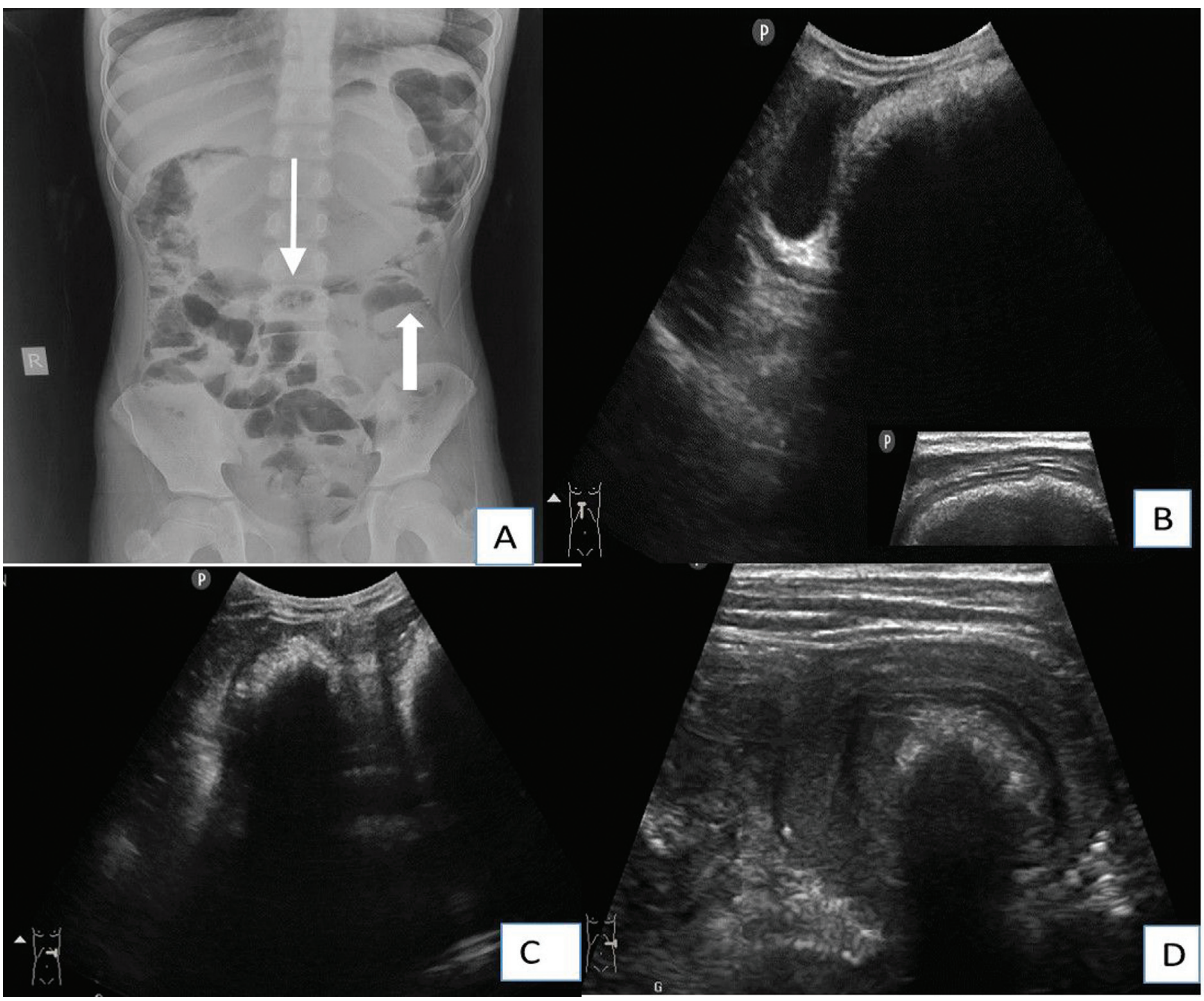

Fig. 17 Trichobezoar with Rapunzel syndrome. A 7-year-old female presented with diffuse pain abdomen and epigastric fullness. (**A**) Erect abdominal radiograph reveals a soft tissue opacity in the stomach with downward displacement of transverse colon (arrow). No abnormal air-fluid levels or free air noted. An intraluminal soft tissue opacity is seen in a jejunal loop in the left lumbar region (thick arrow). (**B**, **C**) Transverse ultrasonography (USG) images demonstrating an intraluminal mass in the stomach and duodenum with a hyperechoic arc-like surface and a marked posterior acoustic shadow. Inset in **B** shows gut signature wall confirming that the mass is intraluminal. (**D**)Transverse USG image in the left lumbar quadrant shows a small bowel intussusception with bezoar as lead point.

trapped in the gastric mucosal folds. They are commonly confined to the stomach but may continue to grow in size and extend through the pylorus into the small intestine (Rapunzel syndrome). Due to rarity and slow-growing nature, this entity is rarely suspected clinically, and most cases are diagnosed late with complications like gastric/intestinal obstruction, perforation, and small bowel intussusception, etc.[28,29]

On conventional radiographs, bezoars appear as mottled radiolucencies in the interstices of a radiopacity. On USG, a bezoar appears as intraluminal mass with a hyperechoic arc-like surface and a marked posterior acoustic shadow different from "dirty" shadowing produced by intraluminal gas or food particles (►**Fig. 17**). However, the entire trajectory of bowel loops cannot be traced on USG and hence CT is the imaging modality of choice to detect complete extent/any additional bezoars. On CT, bezoar appears as a low-density intraluminal mass containing air foci leading to a characteristic mottled appearance (►**Fig. 18**).

Infectious Enterocolitis

Various pathogens like *Salmonella*, *Shigella*, *Escherichia Coli*, and *Campylobacter* cause bacterial enterocolitis. USG is usually not indicated in these cases. However, in patients with pain of moderate to severe intensity, it is helpful to rule out other causes. Ultrasound findings include circumferential bowel wall thickening, hyperechogenicity of submucosa, and hyperemia, usually in the terminal ileum and cecum. Regional lymphadenopathy and increased echogenic mesenteric fat with mild free fluid are common. Viral gastroenteritis does not usually cause bowel wall thickening, although mild ascites and enlarged nodes may be present.[30]

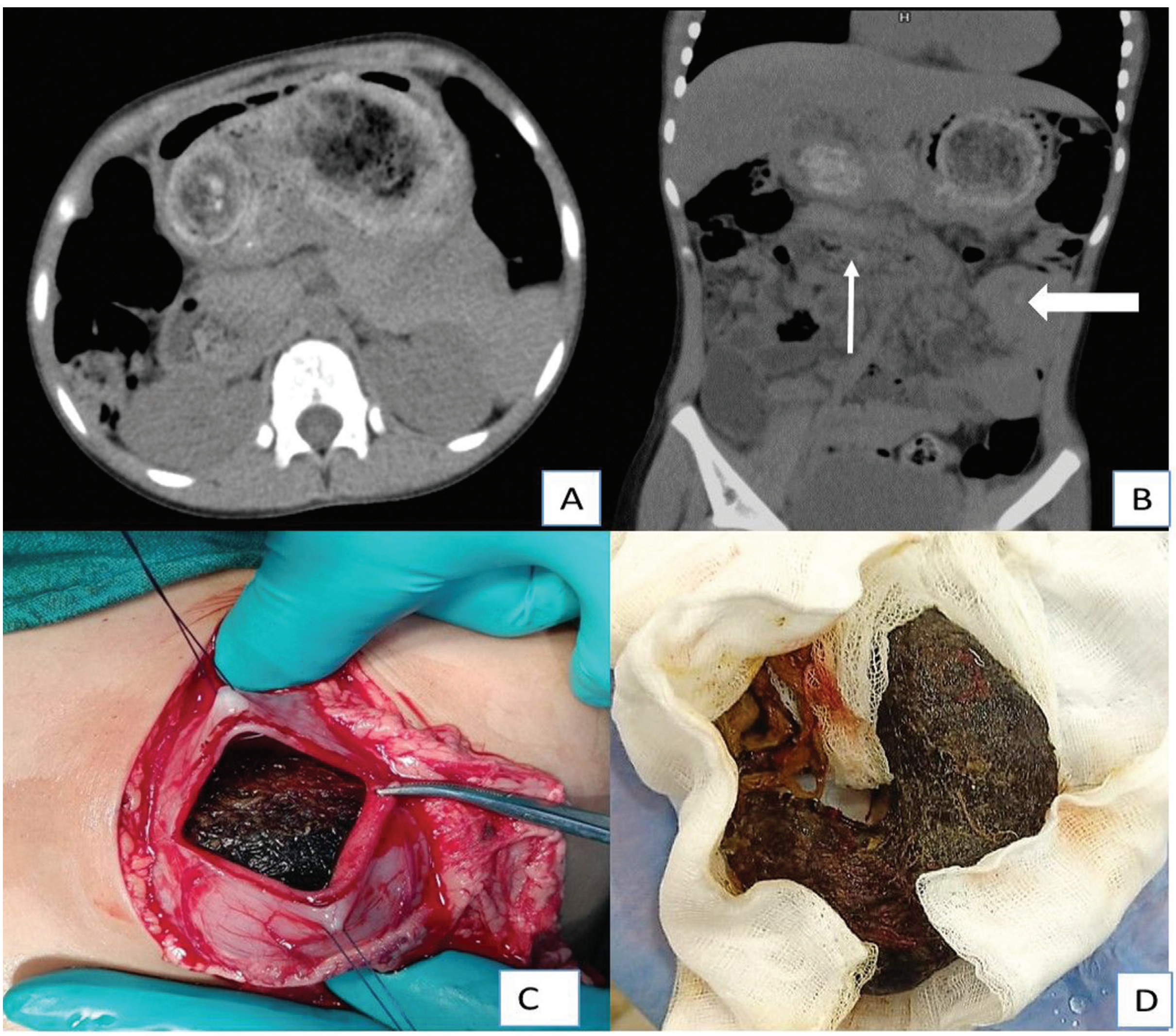

Fig. 18 Same patient as ►**Fig. 17**. (**A**, **B**) Transverse and coronal noncontrast computed tomography (NCCT) images demonstrating well-defined large heterogeneously hyperdense intraluminal mass of mixed air and soft tissue density in the stomach and pylorus. The content is seen extending into the duodenum, crossing the midline (thin arrow in **B**) and extending into the jejunal loops forming a lead point of jejunojejunal intussusception (thick arrow in **B**). (**C**) Intraoperative image with gastrotomy revealing trichobezoar in the stomach. (**D**) Specimen showing en masse gastrointestinal bezoar.

Table 1 Clinical and ultrasound features of acute pediatric GI pathologies

S. No.	Entity	Clinical features	Ultrasound findings
1.	Acute appendicitis	Pain beginning in periumbilical region migrating to RIF ± fever, nausea, anorexia	• MOD ≥ 7 mm • Noncompressibility • Loss of submucosal integrity[a] • Periappendiceal collection[a] • Appendicolith[a]
2.	Midgut volvulus	Bilious vomiting and pain abdomen, usually within 1 year of age	• Intestinal *whirlpool* sign • Absence of retromesenteric duodenum • Inverse relationship of SMA-SMV
3.	Intussusception	Most cases between 6 and 18 months of age with colicky pain abdomen ± blood in stool Complicated cases: Nonpassage of stools and persistent pain abdomen	Bowel in bowel appearance giving the *pseudokidney* and *target* sign • Proximal bowel obstruction[b] • Ascites[b] • Interloop fluid[b]
4.	Meckel's diverticulitis	Bleeding per rectum/periumbilical/pain in RIF/abdominal distension due to obstruction	• Cystic/tubular structure in RIF with gut signature in the wall • NOT arising from the cecum • Surrounding inflammatory changes
5.	Intestinal perforation	Diffuse abdominal pain with abdominal distension and obstipation	Multiple, extraluminal, parallel echogenic lines with ring-down artifacts ("*peritoneal* stripe" sign) or smaller echogenic foci with comet-tail artifacts over RUQ, that displace with change in patient's position
6.	Intestinal obstruction	Abdominal distension and obstipation	• Luminal caliber of small bowel loops of > 3 cm • Hyperperistalsis • Transition point: look for cause of obstruction in this region
7.	Abdominal tuberculosis	Diffuse pain abdomen/bowel obstruction/abdominal distension	• Intestinal: Circumferential terminal ileal, ICJ, and cecal thickening • Peritoneal: Peritoneal/omental thickening, ascites with septations and echoes • Lymph nodal: enlarged, discrete, or conglomerated hypoechoic retroperitoneal/mesenteric lymph nodes ± calcification
8.	Ascariasis	Diffuse pain abdomen, may present with bowel obstruction	Intraluminal structures with echogenic walls and central hypoechogenicity, appearing tubular in longitudinal and doughnut-like in transverse sections
9.	Hypertrophic pyloric stenosis	Neonate/young infant with nonbilious vomiting	• Elongated and thickened pylorus measuring > 15 mm in length and > 3 mm in thickness • *Antral nipple* and *cervix* sign
10.	Bezoar	Diffuse pain abdomen/intestinal obstruction or perforation	Intraluminal content with hyperechoic arc-like surface with marked posterior shadowing
11.	Infective enterocolitis	Fever with pain abdomen	Circumferential bowel wall thickening with hyperechogenicity of submucosa in the terminal ileum and cecum ± regional lymphadenopathy, mild free fluid

Abbreviations: GI, gastrointestinal; ICJ, ileocecal junction; MOD, maximum outer wall to wall diameter; RHQ, right upper quadrant; RIF, right iliac fossa; SMA, superior mesenteric artery; SMV, superior mesenteric vein.
[a]Features that indicate complicated cases of appendicitis.
[b]Features that indicate complicated cases of intussusception.

►**Table 1** summarizes the salient clinical and ultrasound features of various acute nontraumatic GI pathologies.

Conclusion

USG still remains at the forefront in imaging evaluation of acute abdomen, especially in the pediatric population. Various pathologies of the GI tract can be diagnosed using USG. Radiologists need to be acquainted with the normal and abnormal appearances of bowel ultrasound, and attention to technique will enable them to make optimal use of this modality and its dynamic capabilities. This can aid the clinicians in making management decisions, as well as in decreasing the mortality and morbidity rates by early detection of complications.

Conflict of Interest
None declared.

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