Review

Med Ultrason 2025, Vol. 27, no. 1, 63-72
DOI: 10.11152/mu-4414

An [illustrative] update on pediatric emergency medicine ultrasound: part 2 – abdominal and urogenital applications

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Abstract

Emergency ultrasound, or point-of-care ultrasound (POCUS), has been established into daily patient care over the last decades. The use of abdominal and pelvic ultrasound in clinical practice has the potential to improve the efficiency and safety of pediatric emergency care. This article will provide a review of current applications of pediatric emergency abdominal and urogenital ultrasound, forming the second part of the series.

Keywords: pediatric emergency; acute abdomen; point of care; ultrasound

Introduction

Emergency ultrasound, otherwise known as point-of-care ultrasound (POCUS), has become a growing area across pediatric emergency medicine practice. It is a non-invasive and radiation-free diagnostic technology for children, improving procedural time, accuracy, and safety [1-6]. Pediatric emergency medicine physicians are increasingly using POCUS in their practice [7], and guidelines for specialty-specific ultrasound applications have been published [8-11].

The role of POCUS in the care of pediatric patients overlaps with adult applications, but pediatric-specific applications are increasingly being described and studied [1,2,11]. There are several key abdominal anatomical differences between children and adults, including thinner abdominal wall, proportionally larger solid organs, and the bladder is intraabdominal in infants, progressively becoming a pelvic organ in a young child [12]. Given that children often have less subcutaneous tissue and have a smaller body habitus than adults, higher frequency probes can be used to obtain higher resolution images. However, smaller probes with smaller footprints may be required, particularly for smaller acoustic windows. There are also various diseases and conditions that are specific to children [13-18]. In this review, we describe the current applications for abdominal and urogenital POCUS in pediatric emergency department (ED) patients.

Received 30.04.2024 Accepted 26.06.2024
Med Ultrason
2025, Vol. 27, No 1, 63-72
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Gastrointestinal applications

Intestinal atresia and ileus

Ultrasound can diagnose congenital intestinal stenosis, atresia, and very rare intestinal pathology [19,20]. Prestenotic intestinal segments are clearly dilated and distended on ultrasound, post stenotic intestinal segments are usually narrowed, and a caliber shift can sometimes be visualized. Duodenal atresia is identified by marked dilatation of the bulbus duodeni and stomach (double bubble on antenatal ultrasound), often with a dilated pylorus [21] (fig 1), whereas children with anal atresia present with a dilatation of the colon on ultrasound (fig 2). Ultrasound can be used to identify the location of intestinal obstruction [21].

Volvulus and malrotation

Midgut volvulus in association with malrotation is a pediatric surgical emergency. Prompt and accurate diagnosis is necessary to avoid bowel ischemia and necrosis, thereby reducing morbidity and mortality [22]. Ultrasound features suggesting the presence of malrotation include a superior mesenteric vein (SMV) located anterior to or to the left of the SMA-aorta axis, an intraperitoneal course of the third portion of the duodenum anterior to the SMA (rather than its normal retroperitoneal course between the aorta and the SMA), abnormal cecal position (or only small bowel in the right lower quadrant), and a hypoplastic pancreatic uncinate process (not extending posteriorly to the superior mesenteric vessels) [22]. Ultrasound has excellent diagnostic accuracy and is cost effective [23]. However, intestinal gas overlay can complicate the sonographic diagnosis of volvulus. Under ideal examination conditions, the whirlpool sign can be visualized, in which the mesenteric vessels rotate around each other (fig 3).

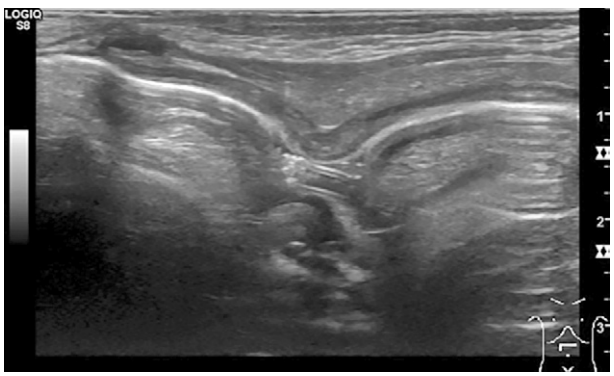

Fig 1. Duodenal atresia in a newborn infant. Cross-section of the upper abdomen showing marked dilatation of the duodenal bulb and stomach (double bubble). Both compartments are filled with gas, represented by reverberation artifacts. The inserted gastric tube passes through the dilated pylorus and extends into the duodenal bulb.

Hypertrophic pyloric stenosis

Hypertrophic pyloric stenosis (HPS) is the most common cause of intestinal obstruction among infants presenting to the ED and is readily diagnosed using POCUS [24-27]. Starting from a midline subxiphoid view with a linear probe held in transverse, the operator scans to the patient's right side to track the gastric wall until the pylorus is identified in a long axis, which can also be viewed in the transverse axis. Muscle width greater than 3 mm, channel length greater than 17 mm and transverse diameter more than 13 mm are generally considered to be diagnostic of HPS but may not capture all instances [27,28] (fig 4). However, in patients <2 weeks old, the pylorus can initially appear normal, which might give indication to serial scans.

Intussusception

Intussusception is the most common abdominal emergency in early childhood. It has a male predominance, with 70% of cases presenting before the age of 2

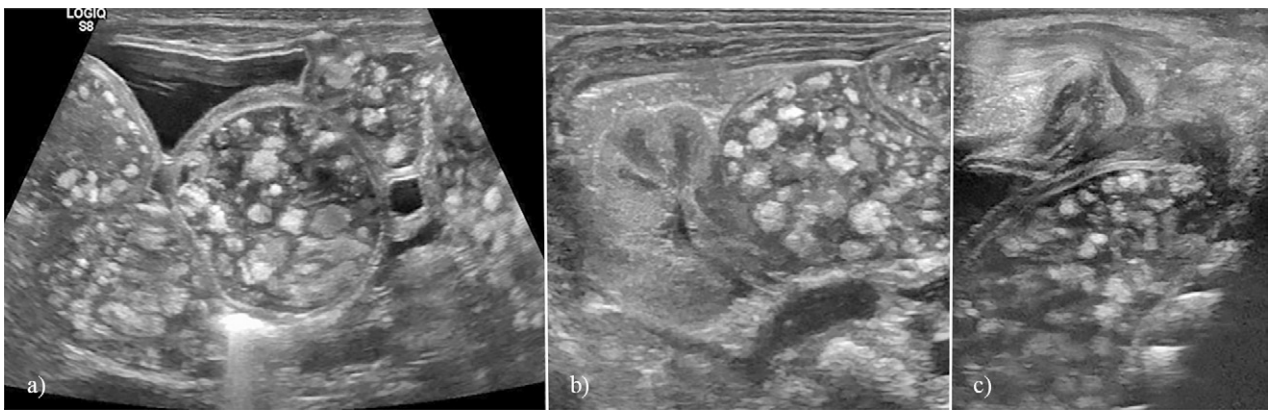

Fig 2. Anal atresia in a newborn infant. Images of severely dilated colonic loops with compression of the urinary bladder and left ureter (a), kidney (b), from the abdominal and rectal blind sac (c) visualized from a perineal window.

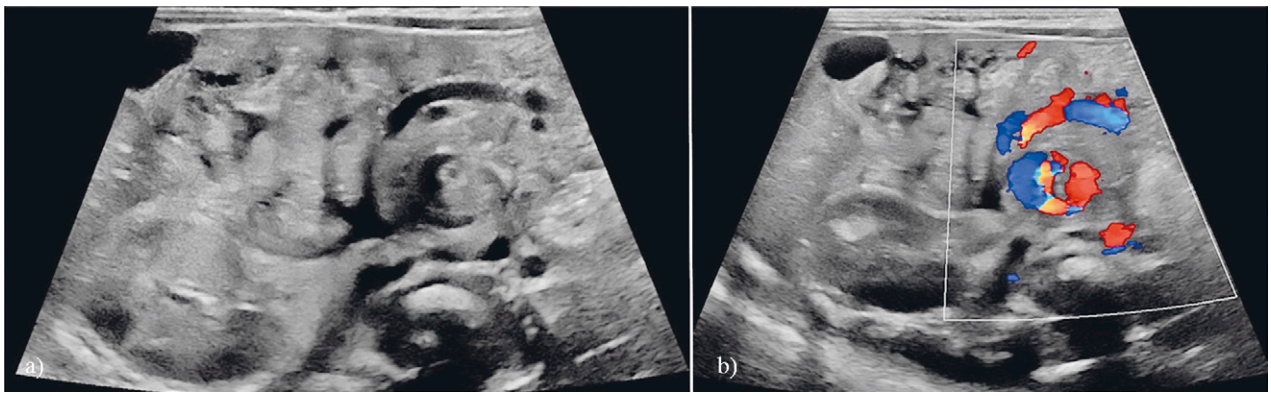

Fig 3. B-mode ultrasound (a) and color flow (b) images of a volvulus with whirlpool sign in a newborn.

years [29]. Ileocolic intussusception is the most common type of intestinal obstruction in children under 36 months of age [30]. Most cases are idiopathic, but several predisposing factors exist, such as cystic fibrosis, Crohn's disease, lipomas, anatomical variations, and intestinal infections [30-32]. Ileocolic intussusception is usually detected on the right side of the abdomen and shows a concentric target sign with a diameter of ≥2 cm in the transverse view; and a so called 'sandwich' or 'pseudo-kidney' sign in the longitudinal view (fig 5). Ileocolic intussusception needs to be differentiated from ileoileal intussusception, which is managed conservatively. A high-resolution linear transducer is used to scan the colon in cross-section, from the ileocecal region to the transverse colon. Ileocolic intussusception can appear as a 'pseudo-kidney' or 'target' sign, but usually has a diameter usually less than 2 cm and typically spontaneously resolve [33]. A prospective study of PEM providers performing POCUS examination in 82 patients undergoing evaluation for intussusception noted a sensitivity of 85% and specificity of 97% [30].

Focal intestinal perforation and necrotizing enterocolitis

Focal intestinal perforation and necrotizing enterocolitis (NEC) are both neonatal abdominal emergencies. Both conditions primarily affect premature infants in the neonatal intensive care unit and these diagnoses can be supported sonographically. Focal intestinal perforation usually becomes symptomatic with the subsequent development of peritonitis. Early ultrasound findings include complex, echogenic free fluid and evidence of free gas [34] (fig 6). Free gas is usually detected above the liver with the patient lying in the left lateral position [35]. NEC is an acute septic condition caused by bacterial invasion of the intestinal wall [36,37]. Sonographic features include thickened or thinned bowel walls, enhanced peritoneal stripe as a sign of pneumoperitoneum (extramural gas) and dirty shadowing for pneumatosis intestinalis (intramural gas), dilated bowel loops, and intraabdominal free fluid [38]. Gas bubbles, represented as echogenic dots with dirty shadowing, can be visualized in the portal vein and within the liver parenchyma as an early sign of NEC [34,39-41] (fig 7). Color Doppler may show increased signal in the inflamed bowel segments and the absence of signal in necrotic bowel segments. Signs of intestinal perforation again can include echogenic, complex free fluid and free gas [35].

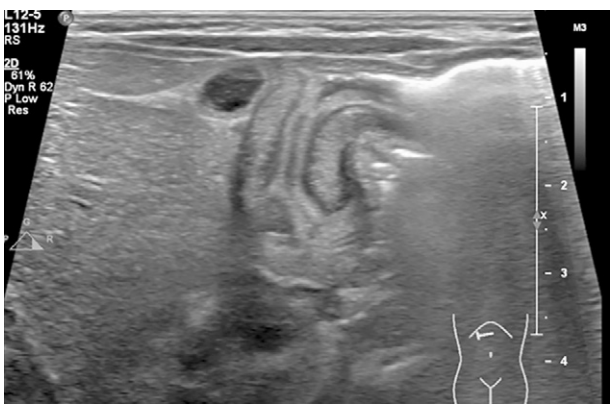

Fig 4. Hypertrophic pyloric stenosis in a 28-day-old infant.

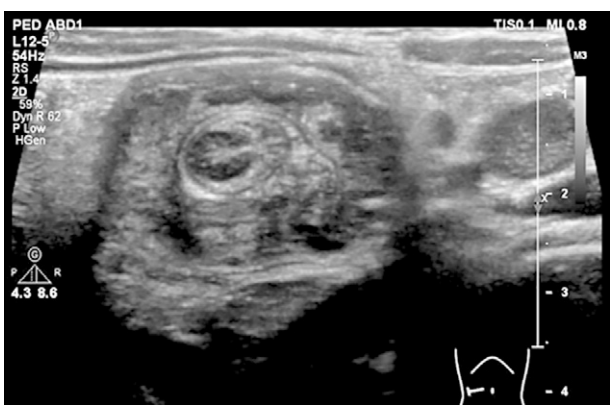

Fig 5. Ileocolic intussusception in a 9-year-old child.

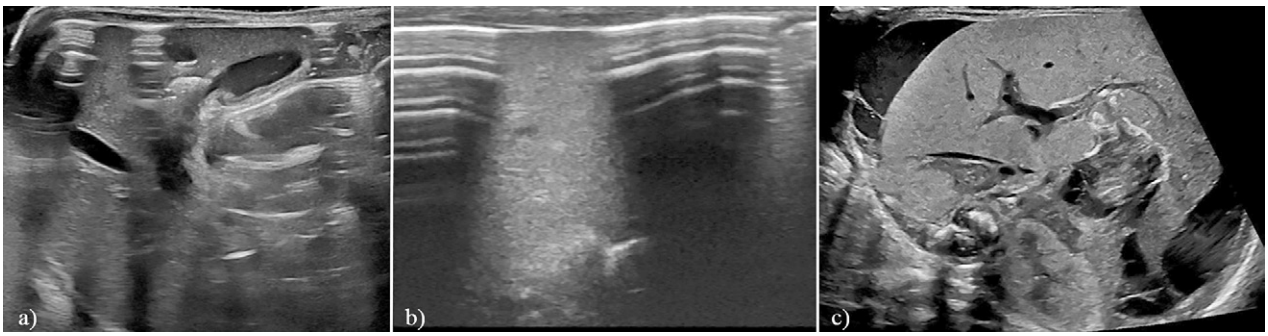

Fig 6. Focal intestinal perforation in a neonate. B-mode ultrasound image of free intra-abdominal gas in the supine position (enhanced peritoneal stripe sign) (a), free gas in left lateral position (b), and complex free fluid (c).

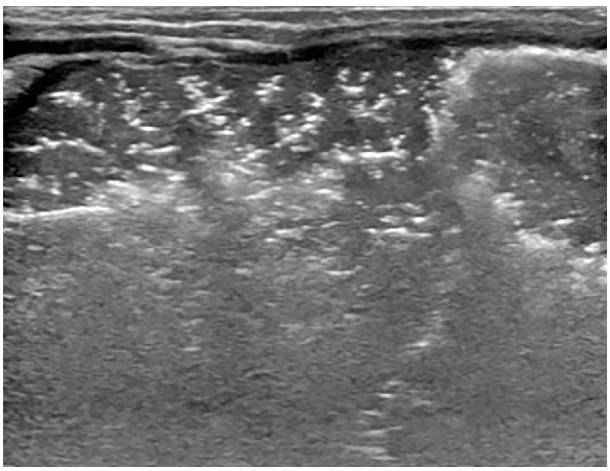

Fig 7. Pneumatosis hepatis and intestinalis in a premature infant with necrotizing enterocolitis. Gas appears as hyperechogenic punctate or tubular structures ith dirty shadowing in the small vessels of the portal system and intestinal wall.

Appendicitis

Ultrasound is increasingly used as a first-line imaging to evaluate patients suspected of having appendicitis [42]. POCUS is performed on the right lower abdomen of the patient, focusing on the point of maximal pain and scanning along the psoas and iliac vessels [43]. The appendix is identified as a blind ending, tubular structure in the ileocecal region with bowel-wall signature. A non-compressible appendix with a diameter greater than 6 mm and probe tenderness is consistent with appendicitis, and can be accompanied by secondary signs of wall hyperemia, presence of appendicolith, surrounding hyperechoic mesenteric fat, periappendiceal fluid or pelvic free fluid [44] (fig 8). The right upper abdomen should also be examined because the appendix can be subhepatic in young children (fig 9). Reliability of ultrasound increases with duration of symptoms, with higher diagnostic accuracy at 15 - 20 hours after the onset of symptoms and less sensitive in the first few hours (i.e. higher false negative rate). A recent systematic review and meta-analysis of POCUS for appendicitis by emergency providers in pediatric patients showed a sensitivity of 89% and specificity of 97%, with difficulty in visualizing retrocecal appendicitis [45]. The presence of a periappendiceal abscess or large complex pelvic free fluid is highly suspicious for perforation. All sonographic findings of appendicitis should be interpreted in conjunction with clinical findings in the pediatric population [46].

Fig 8. Appendicitis in a 10-year-old child demonstrated as a non-compressible, blind-ending tubular structure measuring 10 mm in diameter with surrounding echogenic mesenteric fat.

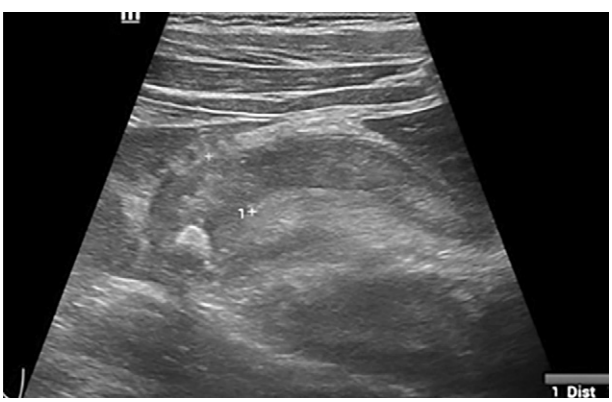

Fig 9. Subhepatic appendicitis with appendicolith in a 5-year-old-girl.

Liver pathologies

Liver injuries with intraabdominal bleeding can result from blunt abdominal trauma, predominately in sports and motor vehicle crashes [47]. When the liver is lacerated or ruptured, discontinuity of the liver capsule, along with changes in the echotexture of the parenchyma and intraabdominal free fluid, can be detected on ultrasound (fig 10) [48]. Sonographic features of hepatic abscesses can vary [49-51]. Early abscesses are often small, indistinct, heterogenous, hypoechoic lesions, which become increasingly anechoic due to liquification of the contents. Gas inclusions can also be observed, indicated by echogenic components with dirty shadowing. Mature abscesses typically exhibit a hypoechoic 'halo' peripherally, which may form a smooth echogenic capsule [52,53]. Suspected abscess is an indication for contrast enhanced ultrasound [49,50]. Due to the dual blood supply of the liver with an arterial and a portal venous blood flow embolic events of the liver are complex especially in patients with congenital vascular anomalies [16,54-56].

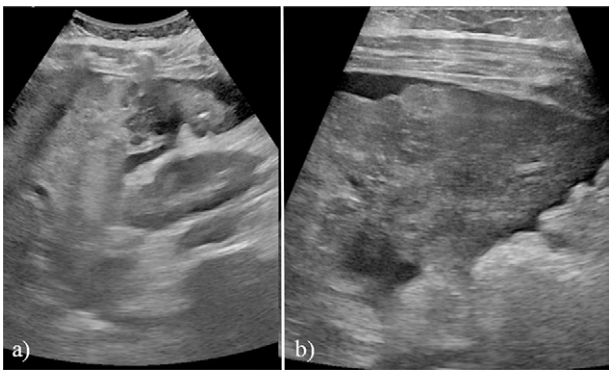

Fig 10. Liver rupture in a 7-year-old girl after being kicked by a horse. B-mode ultrasound with a curved array probe (a) and a high-frequency linear probe (b) in a lateral longitudinal plane.

Gallbladder and biliary pathologies

Although uncommon, cholelithiasis and cholecystitis can be detected in pediatric patients [57-59]. Cholelithiasis is typically characterized by calculi in the gallbladder, identified as echogenic lesions with posterior acoustic shadowing, that move with patient position. However, these can rarely impact in the gallbladder neck or migrate into the biliary tree, causing obstruction and consequent bile duct dilatation (common bile duct diameter upper limit in newborns = 2 mm, infants = 4–6 mm, 14-16 years old = 6 mm) [60]. Cholecystitis can be associated with or without gallstones and is characterized by a thickened, hyperemic gallbladder wall with pericholecystic fluid and probe tenderness (sonographic Murphy's sign) [61]. Adenomyomatosis-related pathology of the gallbladder could be considered in the differential diagnosis of recurrent right abdominal upper quadrant pain in very rare circumstances [62-64]. The normal pediatric gallbladder wall thickness is age dependent but is generally less than 3 mm in a fasted child [60]. Ultrasound-guided percutaneous treatment procedures have been also described in children [65].

Urogenital pathologies

Nephrolithiasis

Nephrolithiasis is an uncommon pediatric condition, but is increasing in its prevalence [66]. POCUS is primarily performed to identify indirect signs of obstructive nephropathy, rather than directly visualizing any calculus. Evidence of a dilated renal collecting system obviously includes hydronephrosis and ureter ectasia. Color Doppler mode may help identify a calculus within the kidney or the proximal or distal ureter, indicated by twinkle artefact [67]. However, calculi cannot usually be visualized in the middle part of the ureter on ultrasound examination. Although studies have shown that the performance of ultrasound for diagnosing pediatric

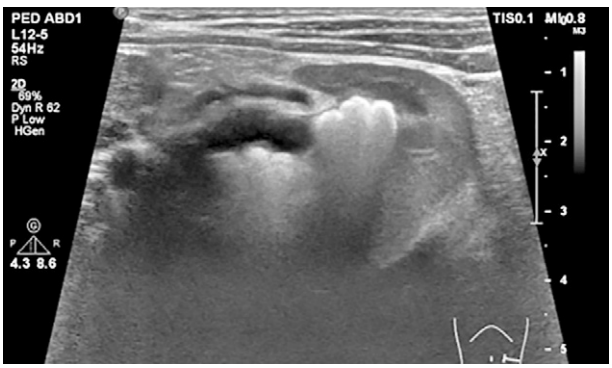

Fig 11. Nephrolithiasis in the left kidney in a 9-year-old child.

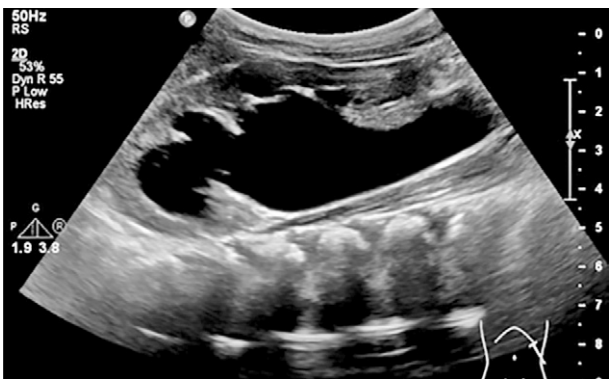

Fig 12. Severe hydronephrosis of the left kidney in an 18-month-old child.

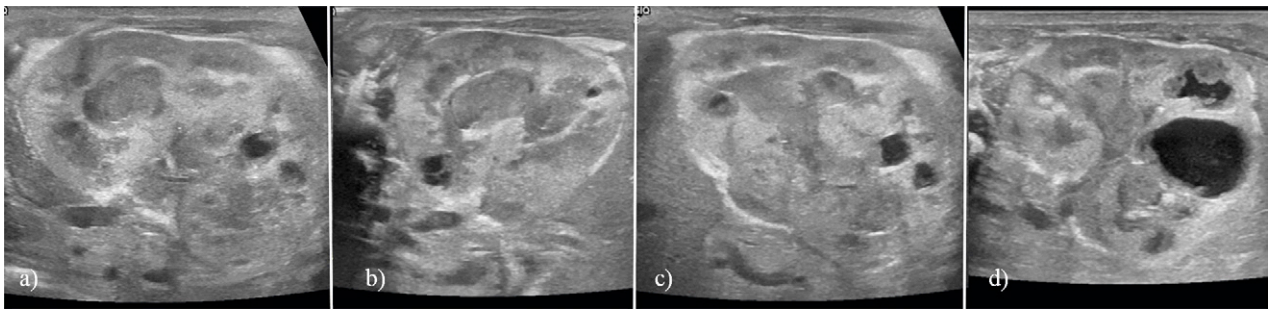

Fig 13. Xanthogranulomatous nephritis caused by Candida species. (a) Inhomogeneous renal parenchyma with abolished medullary rib differentiation and (b) irregularly circumscribed cysts. The renal pelvic caliceal system is shown partially cystically dilated (c), and partially filled with solid material (d).

urolithiasis is not better than that of CT, there are noted advantages including no ionizing radiation and sedation is usually not required [67-69]. POCUS can be used to distinguish abdominal pain caused by nephrolithiasis from other pathologies [70-72] (fig 11-13) and is accurate in ruling out hydronephrosis [73].

Nephrostomy

Percutaneous nephrostomy refers to image-guided placement of a catheter into the renal collecting system, which is typically placed to relieve urinary obstruction. The procedures of percutaneous nephrostomy include patient selection, performing the procedure, monitoring the patient, and longitudinal management of the drainage catheter after the procedure [74]. Ultrasound-guided placement has been described to improve procedural safety and avoid radiation exposure (i.e. CT guidance) [49,50,75].

Urinary bladder

POCUS is performed with a curvilinear probe positioned over the suprapubic area to examine the pediatric bladder in transverse and longitudinal axes, to calculate an estimated bladder volume [76]. Evaluation of bladder volume is helpful prior to urethral catheterization or suprapubic aspiration, particularly in neonates or infants [3,12,61]. POCUS may be also used for needle guidance during suprapubic aspiration [77].

Ovarian torsion

Although uncommon, ovarian torsion can occur in children, including infants and newborns [78]. In pediatric patients, up to half can occur in normal ovaries, with the rest associated with the presence of adnexal masses [79,80]. Ultrasound is the most common method used to rule-in ovarian torsion in pediatric patients. However, a normal study should not be used as a rule-out tool if there is a strong clinical suspicion, given that vascularity is often preserved with normal color Doppler signal [81]. A heterogeneous, asymmetrically enlarged ovary is the most common finding in ovarian torsion, with or without the presence of an adnexal mass [82] (fig 14).

Orchitis and epididymitis

Epididymitis and orchitis are rare in children but have a bimodal distribution of incidence in children under 2 years of age and over 6 years of age [83]. However, it mostly occurs after 6 years of age and can be medically managed [83]. The affected testis and epididymis are typically unilateral and enlarged on ultrasound imaging. They can have either a hypoechoic or hyperechoic echogenicity with characteristic focal increased color Doppler signal, indicative of increased perfusion, compared with the unaffected side. The spectral Doppler shows increased systolic and diastolic flow with low peripheral resistance [84,85].

Testicular torsion

Ultrasound can rule-in the diagnosis of testicular torsion with high accuracy but should not be solely relied upon as a rule-out tool [86,87]. A high-frequency probe with color Doppler is used to determine blood flow in the testicles. A specular view is used to scan both testicles in the same view for comparison. Testicular torsion should be considered when there is a decrease or absence of color Doppler signal in the affected testis (fig 15). It is important to consider torsion-detorsion presentations,

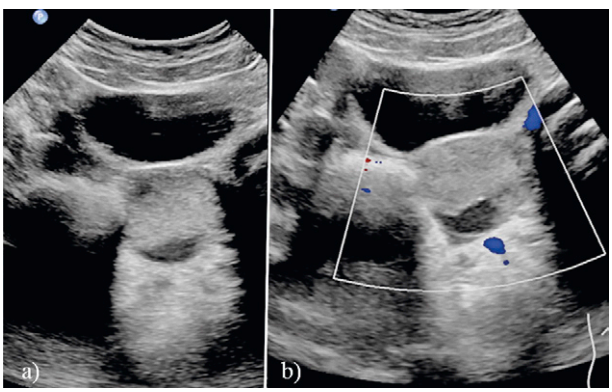

Fig 14. Left ovarian cysts in a 12-year-old child. (a) B-mode ultrasound image and (b) color Doppler image showing lack of flow in the ovary.

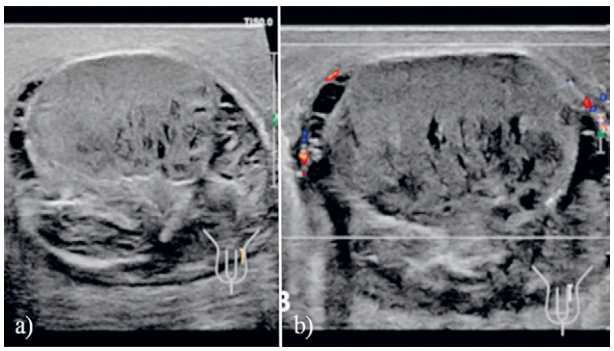

Fig 15. Right testicular torsion in a 13-year-old child. (a) B-mode ultrasound image and (b) color Doppler image with lack of flow.

where flow can be normalized or even hyperemic after detorsion, but the testis may still appear rounded, fixated, and edematous. The twisted spermatic cord can sometimes be visualized on ultrasound, the whirlpool sign, which is highly specific for testicular torsion. A normal ultrasound cannot rule-out testicular torsion, particularly with a high pre-test probability based on clinical presentation.

Conclusion

In this second part of the series, we have outlined the use of POCUS for a range of abdominal and urogenital conditions. Ultrasound is ideal for these applications in children given their thin body habitus allowing high resolution, non-invasive, non-ionizing imaging. Pediatric emergency ultrasound, performed by clinicians, has revolutionized the diagnosis of gastrointestinal, hepatobiliary and urogenital diseases.

Conflict of interest: none

References

1. Chen L, Baker MD. Novel applications of ultrasound in pediatric emergency medicine. Pediatr Emerg Care 2007;23:115-123; quiz 124-116.
2. Levy JA, Noble VE. Bedside ultrasound in pediatric emergency medicine. Pediatrics 2008;121:e1404-1412.
3. Baumann BM, McCans K, Stahmer SA, Leonard MB, Shults J, Holmes WC. Volumetric bladder ultrasound performed by trained nurses increases catheterization success in pediatric patients. Am J Emerg Med 2008;26:18-23.
4. Chen L, Hsiao AL, Moore CL, Dziura JD, Santucci KA. Utility of bedside bladder ultrasound before urethral catheterization in young children. Pediatrics 2005;115:108-111.
5. Nielsen MB, Cantisani V, Sidhu PS, et al. The Use of Handheld Ultrasound Devices - An EFSUMB Position Paper. Ultraschall Med 2019;40:e1.
6. Dietrich CF, Bulla P, Dudwiesus H, et al. [Perspectives and Challenges of hand-held Ultrasound]. Z Gastroenterol 2023;61:836-851.
7. Snelling PJ, Shefrin AE, Moake MM, et al. Establishing the international research priorities for pediatric emergency medicine point-of-care ultrasound: A modified Delphi study. Acad Emerg Med 2022;29:1338-1346.
8. Abo AM, Alade KH, Rempell RG, et al. Credentialing Pediatric Emergency Medicine Faculty in Point-of-Care Ultrasound: Expert Guidelines. Pediatr Emerg Care 2021;37:e1687-e1694.
9. Shefrin AE, Warkentine F, Constantine E, et al. Consensus Core Point-of-care Ultrasound Applications for Pediatric Emergency Medicine Training. AEM Educ Train 2019;3:251-258.
10. Constantine E, Levine M, Abo A, et al. Core Content for Pediatric Emergency Medicine Ultrasound Fellowship Training: A Modified Delphi Consensus Study. AEM Educ Train 2020;4:130-138.
11. Vieira RL, Hsu D, Nagler J, Chen L, Gallagher R, Levy JA. Pediatric emergency medicine fellow training in ultrasound: consensus educational guidelines. Acad Emerg Med 2013;20:300-306.
12. Wheeler J, O'Riordan M, Allareddy V, Speicher D. Would the Use of Bedside Bladder Ultrasound Decrease the Necessity of Invasive Bladder Catheterization in the Pediatric Intensive Care Unit? Clin Pediatr (Phila) 2015;54: 800-802.
13. Dong Y, Cekuolis A, Schreiber-Dietrich D, et al. Review on Pediatric Malignant Focal Liver Lesions with Imaging Evaluation: Part II. Diagnostics (Basel) 2023;13.
14. Dong Y, Cekuolis A, Schreiber-Dietrich D, et al. Review on Pediatric Malignant Focal Liver Lesions with Imaging Evaluation: Part I. Diagnostics (Basel) 2023;13.
15. Cekuolis A, Schreiber-Dietrich D, Augustiniene R, et al. Incidental Findings in Pediatric Patients: How to Manage Liver Incidentaloma in Pediatric Patients. Cancers (Basel) 2023;15.
16. Dietrich CF, Augustiniene R, Batko T, et al. European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB): An Update on the Pediatric CEUS Registry on Behalf of the "EFSUMB Pediatric CEUS Registry Working Group". Ultraschall Med 2021;42:270-277.
17. Chiorean L, Cui XW, Tannapfel A, et al. Benign liver tumors in pediatric patients - Review with emphasis on imaging features. World J Gastroenterol 2015;21:8541-8561.
18. Schreiber-Dietrich DG, Leuschner I, Tannapfel A, et al. [Primary liver tumours in childhood]. Z Gastroenterol 2015;53:1267-1275.
19. Dietrich CF, Lembcke B, Jenssen C, Hocke M, Ignee A, Hollerweger A. Intestinal Ultrasound in Rare Gastrointestinal Diseases, Update, Part 2. Ultraschall Med 2015;36:428-456.
20. Dietrich CF, Chichakli M, Hirche TO, et al. Sonographic findings of the hepatobiliary-pancreatic system in adult patients with cystic fibrosis. J Ultrasound Med 2002;21:409-416; quiz 417.

21. Tsitsiou Y, Calle-Toro JS, Zouvani A, Andronikou S. Diagnostic decision-making tool for imaging term neonatal bowel obstruction. Clin Radiol 2021;76:163-171.
22. Nguyen HN, Navarro OM, Bloom DA, et al. Ultrasound for Midgut Malrotation and Midgut Volvulus: AJR Expert Panel Narrative Review. AJR Am J Roentgenol 2022;218:931-939.
23. Nguyen HN, Sammer MB, Bales B, et al. Time-Driven Activity-Based Cost Comparison of Three Imaging Pathways for Suspected Midgut Volvulus in Children. J Am Coll Radiol 2020;17:1563-1570.
24. Malcom GE 3rd, Raio CC, Del Rios M, Blaivas M, Tsung JW. Feasibility of emergency physician diagnosis of hypertrophic pyloric stenosis using point-of-care ultrasound: a multi-center case series. J Emerg Med 2009;37:283-286.
25. Sharp WW, Chan W. Images in emergency medicine. Infant with projectile vomiting. Peristaltic abdominal waves associated with infantile hypertrophic pyloric stenosis. Ann Emerg Med 2014;63:289,308.
26. Gallagher RA, Levy JA. Advances in point-of-care ultrasound in pediatric emergency medicine. Curr Opin Pediatr 2014;26:265-271.
27. Sivitz AB, Tejani C, Cohen SG. Evaluation of hypertrophic pyloric stenosis by pediatric emergency physician sonography. Acad Emerg Med 2013;20:646-651.
28. Piotto L, Gent R, Taranath A, Bibbo G, Goh DW. Ultrasound diagnosis of hypertrophic pyloric stenosis - Time to change the criteria. Australas J Ultrasound Med 2022;25:116-126.
29. Buettcher M, Baer G, Bonhoeffer J, Schaad UB, Heininger U. Three-year surveillance of intussusception in children in Switzerland. Pediatrics 2007;120:473-480.
30. Riera A, Hsiao AL, Langhan ML, Goodman TR, Chen L. Diagnosis of intussusception by physician novice sonographers in the emergency department. Ann Emerg Med 2012;60:264-268.
31. Dietrich CF, Hollerweger A, Dirks K, et al. EFSUMB Gastrointestinal Ultrasound (GIUS) Task Force Group: Celiac sprue and other rare gastrointestinal diseases ultrasound features. Med Ultrason 2019;21:299-315.
32. Marsicovetere P, Ivatury SJ, White B, Holubar SD. Intestinal Intussusception: Etiology, Diagnosis, and Treatment. Clin Colon Rectal Surg 2017;30:30-39.
33. Leeson K, Leeson B. Pediatric ultrasound: applications in the emergency department. Emerg Med Clin North Am 2013;31:809-829.
34. Trenker C, Gorg C, Dong Y, et al. Portal venous gas detection in different clinical situations. Med Ultrason 2023.
35. Deeg KH. Sonographic and Doppler Sonographic Diagnosis of Necrotizing Enterocolitis in Preterm Infants and Newborns. Ultraschall Med 2019;40:292-318.
36. Dietrich CF. Significance of abdominal ultrasound in inflammatory bowel disease. Dig Dis 2009;27:482-493.
37. Dietrich CF, Hermann S, Klein S, Braden B. Sonographic signs of neutropenic enterocolitis. World J Gastroenterol 2006;12:1397-1402.
38. Shokoohi H, Boniface KS, Abell BM, Pourmand A, Salimian M. Ultrasound and Perforated Viscus; Dirty Fluid, Dirty Shadows, and Peritoneal Enhancement. Emerg (Tehran) 2016;4:101-105.
39. Mishra V, Cuna A, Singh R, Schwartz DM, Chan S, Maheshwari A. Imaging for Diagnosis and Assessment of Necrotizing Enterocolitis. Newborn (Clarksville) 2022;1:182-189.
40. Priyadarshi A, Rogerson S, Cruzado R, et al. Neonatologist-performed point-of-care abdominal ultrasound: What have we learned so far? Front Pediatr 2023;11:1173311.
41. Cui XW, Ignee A, Hocke M, Seitz K, Schrade G, Dietrich CF. Prolonged heterogeneous liver enhancement on contrast-enhanced ultrasound. Ultraschall Med 2014;35:246-252.
42. Gilligan LA, Trout AT, Davenport MS, Zhang B, O'Hara SM, Dillman JR. Predictors of Clinical Outcomes in Pediatric Appendicitis: Role of the Individual Sonographer and Radiologist When Using a First-Line Ultrasound Approach. J Am Coll Radiol 2021;18:1128-1138.
43. Sivitz AB, Cohen SG, Tejani C. Evaluation of acute appendicitis by pediatric emergency physician sonography. Ann Emerg Med 2014;64:358-364.e354.
44. Vasavada P. Ultrasound evaluation of acute abdominal emergencies in infants and children. Radiol Clin North Am 2004;42:445-456.
45. Matthew Fields J, Davis J, Alsup C, et al. Accuracy of Point-of-care Ultrasonography for Diagnosing Acute Appendicitis: A Systematic Review and Meta-analysis. Acad Emerg Med 2017;24:1124-1136.
46. Tulin-Silver S, Babb J, Pinkney L, et al. The challenging ultrasound diagnosis of perforated appendicitis in children: constellations of sonographic findings improve specificity. Pediatr Radiol 2015;45:820-830.
47. Dong Y, Schwarz S, Hoffmann B, et al. An [illustrative] update on pediatric emergency medicine ultrasound: part 1 - trauma and thoracic applications. Med Ultrason 2024, doi: 10.11152/mu-4362.
48. Escudero-Fernandez JM, Bolufer Cardona M, Perez Lafuente M, Montealegre C, Uriarte I, Serres-Créixams X. Active bleeding after kidney biopsy: Successful ultrasound-guided direct thrombin embolization into the cortical fistula. J Clin Ultrasound 2021;49:390-394.
49. Dietrich CF, Lorentzen T, Appelbaum L, et al. EFSUMB Guidelines on Interventional Ultrasound (INVUS), Part III - Abdominal Treatment Procedures (Short Version). Ultraschall Med 2016;37:27-45.
50. Dietrich CF, Lorentzen T, Appelbaum L, et al. EFSUMB Guidelines on Interventional Ultrasound (INVUS), Part III - Abdominal Treatment Procedures (Long Version). Ultraschall Med 2016;37:E1-E32.
51. Dietrich CF, Sharma M, Gibson RN, Schreiber-Dietrich D, Jenssen C. Fortuitously discovered liver lesions. World J Gastroenterol 2013;19:3173-3188.
52. Dietrich CF, Nolsoe CP, Barr RG, et al. Guidelines and Good Clinical Practice Recommendations for Contrast-

Enhanced Ultrasound (CEUS) in the Liver-Update 2020 WFUMB in Cooperation with EFSUMB, AFSUMB, AIUM, and FLAUS. Ultrasound Med Biol 2020;46:2579-2604.
53. Dietrich CF, Nolsoe CP, Barr RG, et al. Guidelines and Good Clinical Practice Recommendations for Contrast Enhanced Ultrasound (CEUS) in the Liver - Update 2020 - WFUMB in Cooperation with EFSUMB, AFSUMB, AIUM, and FLAUS. Ultraschall Med 2020;41:562-585.
54. Moller K, Zadeh ES, Gorg C, et al. Comments and illustrations of the WFUMB CEUS liver guidelines: Rare vascular pathology, part II. Med Ultrason 2023;25:189-200.
55. Moller K, Tscheu T, De Molo C, et al. Comments and illustrations of the WFUMB CEUS liver guidelines: rare congenital vascular pathology. Med Ultrason 2022;24:461-472.
56. Dietrich CF. Comments and illustrations regarding the guidelines and good clinical practice recommendations for contrast-enhanced ultrasound (CEUS)--update 2008. Ultraschall Med 2008;29 Suppl 4:S188-202.
57. Chandra S, Friesen C, Attard TM. Trends in the epidemiology of pediatric acute and chronic cholecystitis-related admissions in the USA: a nationwide emergency department and inpatient sample study. J Investig Med 2019;67:1155-1159.
58. Damman J, Doniger SJ, Atigapramoj N. Neonatal Gallstones Serendipitously Discovered by Point-of-Care Ultrasound in the Pediatric Emergency Department. Pediatr Emerg Care 2016;32:734-735.
59. Tsung JW, Raio CC, Ramirez-Schrempp D, Blaivas M. Point-of-care ultrasound diagnosis of pediatric cholecystitis in the ED. Am J Emerg Med 2010;28:338-342.
60. Sienz M, Ignee A, Dietrich CF. [Reference values in abdominal ultrasound - biliopancreatic system and spleen]. Z Gastroenterol 2011;49:845-870.
61. Lin-Martore M, Kornblith AE. Diagnostic Applications of Point-of-Care Ultrasound in Pediatric Emergency Medicine. Emerg Med Clin North Am 2021;39:509-527.
62. Jenssen C, Nolsoe C, Lorentzen T, et al. Incidental findings of gallbladder and bile ducts – Management strategies: Normal findings, anomalies, "silent gallstones" and bile duct dilatation - A World Federation of Ultrasound in Medicine and Biology (WFUMB) position paper. WFUMB Ultrasound Open 2024 (epub in advance).
63. Jenssen C, Lorentzen T, Dietrich CF, et al. Incidental Findings of Gallbladder and Bile Ducts-Management Strategies: General Aspects, Gallbladder Polyps and Gallbladder Wall Thickening-A World Federation of Ultrasound in Medicine and Biology (WFUMB) Position Paper. Ultrasound Med Biol 2022;48:2355-2378.
64. Almasoud A, Alvarez F, Deslandres C. Adenomyomatosis of the Gallbladder as a Cause of Abdominal Pain in Pediatrics: A Case Report of an Adolescent and a Literature Review. JPGN Rep 2023;4:e378.
65. Ignee A, Baum U, Schuessler G, Dietrich CF. Contrast-enhanced ultrasound-guided percutaneous cholangiography and cholangiodrainage (CEUS-PTCD). Endoscopy 2009;41:725-726.
66. Cao B, Daniel R, McGregor R, Tasian GE. Pediatric Nephrolithiasis. Healthcare (Basel) 2023;11.
67. Riera A, Bokhari SA, Bechtel K. If You Twinkle When You Tinkle, Stones Are Found on Ultrasound. Pediatr Emerg Care 2016;32:246-249.
68. Ng C, Tsung JW. Avoiding Computed Tomography Scans By Using Point-Of-Care Ultrasound When Evaluating Suspected Pediatric Renal Colic. J Emerg Med 2015;49:165-171.
69. Chandra A, Zerzan J, Arroyo A, Levine M, Dickman E, Tessaro M. Point-of-care ultrasound in pediatric urolithiasis: an ED case series. Am J Emerg Med 2015;33:1531-1534.
70. Thorpe EL, Marin JR. Identification of unanticipated pelvic pathology on renal bedside ultrasound. Pediatr Emerg Care 2013;29:537-540.
71. Arlen AM, Merriman LS, Kirsch JM, et al. Early effect of American Academy of Pediatrics Urinary Tract Infection Guidelines on radiographic imaging and diagnosis of vesicoureteral reflux in the emergency room setting. J Urol 2015;193:1760-1765.
72. Halm BM. Diagnosis of an Acute Lobar Nephronia in the Emergency Department Using POINT-OF-CARE Ultrasound. J Emerg Med 2019;57:227-231.
73. Guedj R, Escoda S, Blakime P, Patteau G, Brunelle F, Cheron G. The accuracy of renal point of care ultrasound to detect hydronephrosis in children with a urinary tract infection. Eur J Emerg Med 2015;22:135-138.
74. Cahill AM, Annam A, Baskin KM, et al. Society of Interventional Radiology Quality Improvement Standards for Percutaneous Nephrostomy in the Pediatric Population. J Vasc Interv Radiol 2021;32:146-149.
75. Cui XW, Ignee A, Maros T, Straub B, Wen JG, Dietrich CF. Feasibility and Usefulness of Intra-Cavitary Contrast-Enhanced Ultrasound in Percutaneous Nephrostomy. Ultrasound Med Biol 2016;42:2180-2188.
76. Snelling PJ. Getting started in paediatric emergency medicine point-of-care ultrasound: Five fundamental applications. Australas J Ultrasound Med 2020;23:5-9.
77. Kiernan SC, Pinckert TL, Keszler M. Ultrasound guidance of suprapubic bladder aspiration in neonates. J Pediatr 1993;123:789-791.
78. Guthrie BD, Adler MD, Powell EC. Incidence and trends of pediatric ovarian torsion hospitalizations in the United States, 2000-2006. Pediatrics 2010;125:532-538.
79. Rody A, Jackisch C, Klockenbusch W, Heinig J, Coenen-Worch V, Schneider HP. The conservative management of adnexal torsion--a case-report and review of the literature. Eur J Obstet Gynecol Reprod Biol 2002;101: 83-86.
80. Anders JF, Powell EC. Urgency of evaluation and outcome of acute ovarian torsion in pediatric patients. Arch Pediatr Adolesc Med 2005;159:532-535.
81. Servaes S, Zurakowski D, Laufer MR, Feins N, Chow JS. Sonographic findings of ovarian torsion in children. Pediatr Radiol 2007;37:446-451.

82. Edmunds K, Gurria J, Koberlein G, et al. Vomiting and Dehydration in a 2-Year-Old. Pediatrics 2019;143.
83. Aso C, Enríquez G, Fité M, et al. Gray-scale and color Doppler sonography of scrotal disorders in children: an update. Radiographics 2005;25:1197-1214.
84. Horstman WG, Middleton WD, Melson GL. Scrotal inflammatory disease: color Doppler US findings. Radiology 1991;179:55-59.
85. Jee WH, Choe BY, Byun JY, Shinn KS, Hwang TK. Resistive index of the intrascrotal artery in scrotal inflammatory disease. Acta Radiol 1997;38:1026-1030.
86. Keays M, Rosenberg H. Testicular torsion. Cmaj 2019;191:E792.
87. Sharp VJ, Kieran K, Arlen AM. Testicular torsion: diagnosis, evaluation, and management. Am Fam Physician 2013;88:835-840.