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Letter to the Editor

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Pediatric Abdominal Ultrasound Training Program: Standard Views

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ABSTRACT

The use of abdominal ultrasound is becoming a necessity, rather than an option, for pediatricians. Incorporating abdominal ultrasound training into resident training programs for pediatricians provides a direct pathway for physicians to effectively utilize point-of-care ultrasound (POCUS) in their clinical practice after board certification. This study proposed a detailed system to support this initiative by establishing 22 standard views of pediatric abdominal ultrasound and emphasizing a structured training regimen with repeated practice to achieve proficiency. This approach offers a streamlined method for trainees to become experts rapidly. After board certification, this foundational training serves as the basis for advanced learning, allowing clinicians to tailor POCUS techniques according to their specific areas of practice.

Keywords: Point-of-care ultrasound; Pediatric; Abdomen; Ultrasounds; Republic of Korea

INTRODUCTION

The author recently published articles in *Pediatric Gastroenterology, Hepatology & Nutrition* emphasizing the necessity of establishing an abdominal ultrasound training system for pediatric residents and outlining abdominal ultrasound techniques for pediatricians in clinical and experimental pediatrics. Since 2010, the use of ultrasound by non-radiologists has been actively adopted, with their specialized point-of-care ultrasound (POCUS) being widely utilized in various fields, such as Emergency Medicine, Surgery, Neonatal Intensive Care Unit (NICU), Anesthesiology, and Urology [1]. In recent years, there has been an active surge in POCUS research in the fields of Emergency Medicine, NICU, PICU, and Surgery. It is now time for general pediatricians to also begin incorporating POCUS into their practice [2-5]. While the *Clinical and Experimental Pediatrics* article introduced the concept of standard views [6], further consideration was given to optimizing the training system for pediatric residents within the specific context of the domestic resident training environment. This study revisits and refines the concept of standard views to better suit our training conditions. Although the prevalence of pediatric obesity has increased, advances in ultrasound technology have significantly enhanced its diagnostic capabilities. Unlike in adults, the smaller body size of children often limits the diagnostic utility of computed tomography (CT), which excels in providing detailed imaging. In contrast, the limitations of ultrasound in adults are less pronounced in children, making the combined use of CT and ultrasound particularly beneficial for ambiguous diagnoses. There is a broad consensus that foundational ultrasound training should begin during residency. However, many training institutions lack attending physicians who perform pediatric abdominal ultrasounds relevant to primary care. Instead, attending physicians often focus on advanced POCUS applications (e.g., hepatic or intestinal ultrasound) tailored to their specialties [7-9], making traditional apprenticeship-style training for residents challenging. To address this gap, a structured training program is essential to familiarize residents with pediatric abdominal ultrasound techniques applicable to primary care. Such programs would not only prepare residents for primary care POCUS but also alleviate attending physicians' concerns about teaching unfamiliar topics. This study proposed a robust training program that will facilitate the training of pediatricians nationwide, enabling the routine use of ultrasound in pediatric clinical practice.

In primary care, POCUS refers to the diagnostic findings that pediatricians typically expect when referring to abdominal ultrasounds in radiology. Historically, these findings have been established through pediatric abdominal ultrasound interpretations. In 2011, Park [10] directly performed pediatric abdominal ultrasounds to diagnose gastrointestinal diseases and analyzed the interpretations of 1,000 patients. Radiologists are aware that ultrasound or CT alone cannot provide a definitive diagnosis in 100% of the cases. Therefore, they strive to identify additional factors beyond ultrasound or CT that are necessary to ensure an accurate diagnostic approach. We need to learn and develop the ability to interpret ultrasound and CT findings. However, if we fully understand the unique advantages that we possess as pediatric specialists–the advantages that radiologists may not have–it will greatly enhance our training in abdominal ultrasound [11-13]. A common concern among beginners performing abdominal ultrasound is the fear of missing findings that others may detect, leading to a lack of confidence. Therefore, addressing this fear is critical. To ensure comprehensive examinations and minimize omissions, the author organized a checklist of key diagnostic images for pediatric abdominal ultrasound. This approach conceptually aligns with the mandatory imaging criteria required for insurance reimbursements for adult abdominal ultrasounds. The author defined these key diagnostic images as 22 standard views and explained their relevance to specific diseases and diagnostic utility [14-17]. While some images may not meet the insurance criteria owing to the challenges posed by a patient's abdominal condition that even experts might find difficult to capture, understanding these 22 standard views and consistently striving to acquire them can transform any clinician into a competent pediatric abdominal ultrasound expert through practice, even without traditional apprenticeship training.

DISCUSSION

Ultrasound examination involves understanding the anatomy and capturing images of the structures of interest. To achieve this, an ultrasound probe must be visualized by projecting a fan-shaped beam outside the skin to create a two-dimensional image on a monitor. Simultaneously, the examiner must mentally reconstruct the corresponding three-dimensional (3D) anatomical structures. This requires a solid foundational understanding of the key anatomical landmarks and the ability to differentiate between normal (**Fig. 1A, B**) and abnormal structures on the ultrasound screens. Understanding normal anatomical structures should be selective, focusing on those that are critical for examination. Additional knowledge of less commonly encountered structures can be developed through repeated ultrasound

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practice and by consulting advanced resources such as textbooks or online materials. This iterative process is effective in accelerating expertise. To enhance familiarity with selected normal structures, studying anatomical texts, observing and creating 3D anatomical models, and reviewing abdominal CT or magnetic resonance imaging (MRI) scans may be highly beneficial. Both CT and MRI generate two-dimensional images derived from 3D anatomy, similar to ultrasound, and can significantly aid in the development of a mental framework for interpreting ultrasound images. These supplementary modalities provide valuable context and improve the examiner's ability to navigate ultrasound screens with confidence.

The primary challenge in ultrasound imaging is the presence of gases. When ultrasound waves encounter a gas, they produce bright high-echo artifacts, creating a barrier that prevents visualization beyond the gas. Experts often manage this by compressing and displacing the gas or altering the probe position to circumvent it. However, a more effective preparation involves removing the obstruction entirely, such as by using enemas. Appropriate preparation is particularly crucial in cases where visualization is essential. Thus, caution is necessary when dealing with situations such as bowel perforation or when considering aggressive bowel preparation methods, such as those used for colonoscopy, as these could worsen the patient's condition. Pre-examination fasting is also a critical component, not only because it helps distend the gallbladder (GB) but also because it minimizes gas production, thereby improving imaging conditions. In pediatric patients, performing an enema instead of relying on sedation offers several advantages. It allows the assessment of stool condition, often alleviates abdominal pain, and serves as an effective preparation for ultrasound examinations. This straightforward approach can significantly enhance the diagnostic value of this procedure, particularly in young children.

Before mastering the 22 standard views, it is essential to understand the characteristics of the echoes displayed on the ultrasound screen. As mentioned previously, gas-filled media produce bright high-echo boundaries, beyond which imaging is impossible. Calcifications also appear as high-echo structures but differ from gas in that imaging beyond the small calcification is still visible. Stones resemble calcifications in their high-echo appearance; however, large stones are characterized by acoustic shadowing, which is a distinct feature. Simple cysts found in most solid organs have well-defined margins and appear as anechoic structures. However, complex cysts may exhibit additional features such as septations or solid components. Tumors, however, vary in echogenicity depending on the composition of their internal material, appearing either heterogenous or homogenous. Blood flow, being a fluid, is typically anechoic and can be visualized using Doppler ultrasound, which displays the direction and speed of the flow in red or blue, depending on the relative motion of the probe. Understanding these echo characteristics provides a critical foundation for the accurate interpretation of images obtained from standard views.

Visualization of key anatomical landmarks is essential for mastering pediatric abdominal ultrasound. A fundamental exercise involves identifying and sketching the "H-shaped" left portal vein, which serves as a guide for understanding the left lobe of the liver (**Fig. 1C**). In newborns, the residual ductus venosus can sometimes be mistaken for a thrombus, emphasizing the need for careful interpretation. Another critical exercise is tracing the transition from the gastric antrum to the pyloric canal, using the liver as an acoustic window (**Fig. 1D**). This practice aids in the diagnosis of idiopathic hypertrophic pyloric stenosis, a condition commonly observed during the neonatal period. In the epigastric region, the portal vein emerges from the liver and forms the splenic vein, with the pancreas resting above

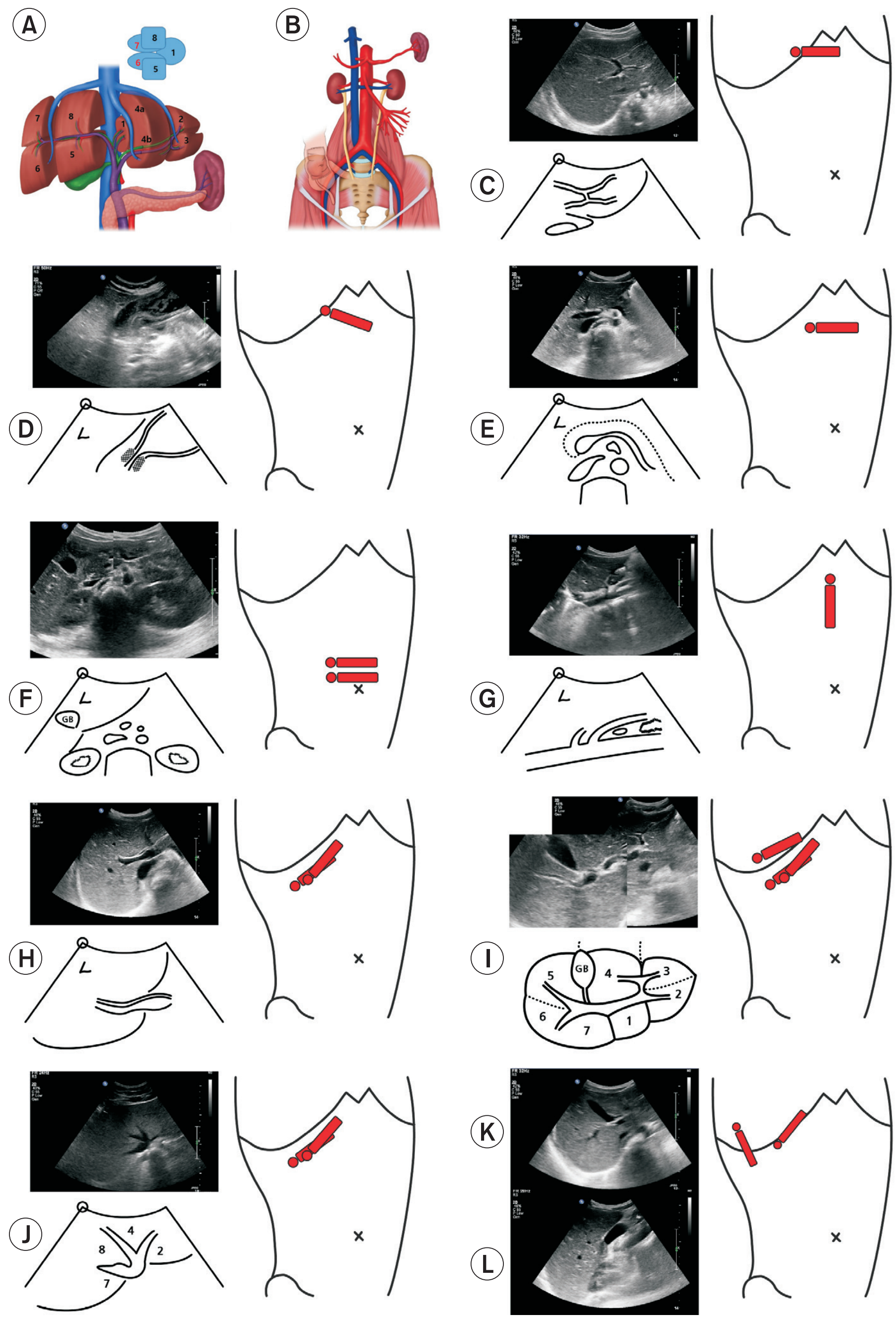

Fig. 1. Eight segments of the liver with hepatic veins and portal veins, splenic vein, pancreas, SMV, SMA, and spleen (A). IVC, aorta, spleen, both kidneys, and lower abdomen anatomy (B). Left lobe with H-shaped left portal vein (C). Liver, pyloric canal, and antrum of the stomach (D). Transverse view of the pancreas with the SMA (E). Transverse view of the liver, GB, vetebrae, SMV, SMA, IVC, aorta, and both kidneys (F). Longitudinal view of the SMA branching from the aorta (G). CBD and portal vein to splenic vein (H). GB, right to left portal vein, and segments 1, 2, 3, 4, 5, 6, and 7 (I). Bunny sign in the right, middle, and left hepatic veins (J). View of the GB from two directions (K, L). Right kidney with the right hepatic vein (M). Long and short axes of the right kidney (N, O). Right portal vein with hepatic segments 5, 7, and 8 (P). Spleen and left kidney (Q). Long and short axes of the left kidney (R, S). Transverse view of the urinary bladder, pelvic organs, and both psoas muscle and iliac vessels (T). Right psoas muscle, iliac artery and vein, cecum to terminal ileum, and appendix in the right lower quadrant (U). Transverse view of the transverse colon on the upper abdomen (V). Jejunum and descending colon in the left upper quadrant (W). Sigmoid colon, left iliac artery and vein, and left psoas muscle in the left lower quadrant (X).
SMV: superior mesenteric vein, SMA: superior mesenteric artery, GB: gallbladder, IVC: inferior vena cava, CBD: common bile duct.

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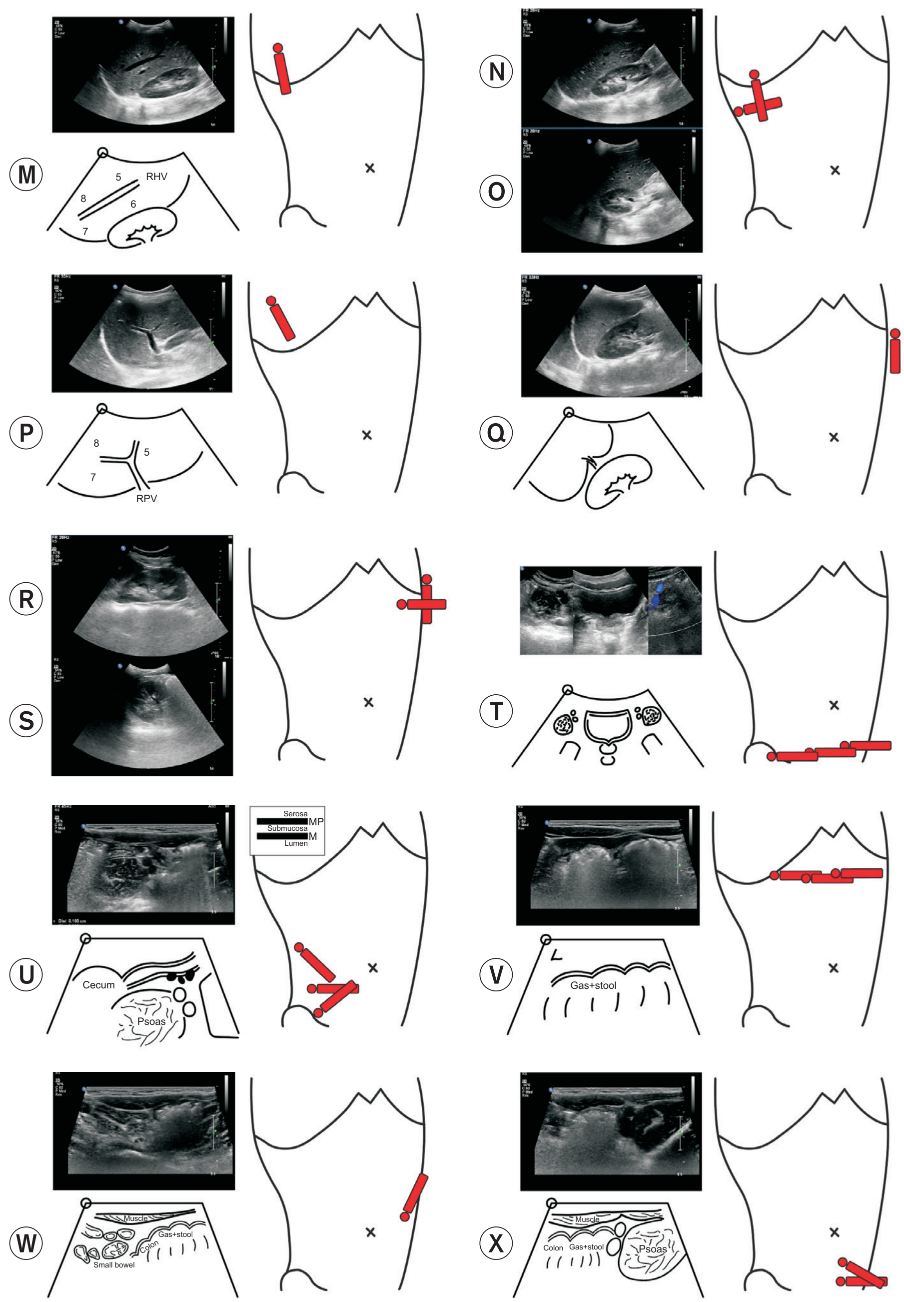

Fig. 1. (Continued) Eight segments of the liver with hepatic veins and portal veins, splenic vein, pancreas, SMV, SMA, and spleen (A). IVC, aorta, spleen, both kidneys, and lower abdomen anatomy (B). Left lobe with H-shaped left portal vein (C). Liver, pyloric canal, and antrum of the stomach (D). Transverse view of the pancreas with the SMA (E). Transverse view of the liver, GB, vetebrae, SMV, SMA, IVC, aorta, and both kidneys (F). Longitudinal view of the SMA branching from the aorta (G). CBD and portal vein to splenic vein (H). GB, right to left portal vein, and segments 1, 2, 3, 4, 5, 6, and 7 (I). Bunny sign in the right, middle, and left hepatic veins (J). View of the GB from two directions (K, L). Right kidney with the right hepatic vein (M). Long and short axes of the right kidney (N, O). Right portal vein with hepatic segments 5, 7, and 8 (P). Spleen and left kidney (Q). Long and short axes of the left kidney (R, S). Transverse view of the urinary bladder, pelvic organs, and both psoas muscle and iliac vessels (T). Right psoas muscle, iliac artery and vein, cecum to terminal ileum, and appendix in the right lower quadrant (U). Transverse view of the transverse colon on the upper abdomen (V). Jejunum and descending colon in the left upper quadrant (W). Sigmoid colon, left iliac artery and vein, and left psoas muscle in the left lower quadrant (X).
SMV: superior mesenteric vein, SMA: superior mesenteric artery, GB: gallbladder, IVC: inferior vena cava, CBD: common bile duct.

it (head, body, and tail). The portal vein descends anteriorly to form the superior mesenteric vein, which is located on the right side of the aorta and branches into the superior mesenteric artery. To the left of the aorta lies the inferior vena cava (**Fig. 1E**). This view facilitates the diagnosis of conditions such as pancreatic swelling, pancreatic duct dilatation, pseudocysts, peripancreatic fluid collection, intestinal malrotation, and midgut volvulus. Positioning the probe transversely just above the umbilicus allows visualization of the vertebrae as a central landmark. The liver and right kidney are on the left side, whereas only the left kidney is visible on the right side of the image (**Fig. 1F**). While gas-filled intestines or obesity may obscure this view, practicing appropriate compression and probe manipulation can help develop the skills needed to consistently achieve this visualization. These exercises not only enhance anatomical understanding but also provide a systematic framework for identifying key structures critical for accurate diagnosis in pediatric abdominal ultrasound. In rare cases, conditions such as omental infarction may be diagnosed in obese children, typically appearing medial to the left hepatic lobe, medial to the right stomach, and superficially near the abdominal wall overlying the deep right kidney. Additionally, the kidneys are frequently associated with various anomalies. For instance, a horseshoe kidney may be present where the lower poles of both the kidneys are connected anteriorly to the vertebrae. By rotating the probe perpendicular to the site shown in **Fig. 1E**, the aorta could be visualized in cross-section, with the celiac trunk and superior mesenteric artery (SMA) branching anteriorly (**Fig. 1G**). The left renal vein and duodenum pass through the aorta and SMA. In emaciated patients, narrowing of this space can compress the left renal vein, causing hematuria (nutcracker syndrome), or compress the duodenum, resulting in vomiting (SMA syndrome). Positioning the probe in the right subcostal region with minimal tilting allows visualization of the portal vein exiting the liver along the common bile duct (**Fig. 1H**). In pediatric patients, if the biliary duct diameter exceeds half the diameter of the adjacent portal vein, ductal dilatation should be assessed. In cases of dilatation, further evaluation of ductal stones or choledochal cysts is required. Thorough examination of the portal triad and liver structures is essential (**Fig. 1A**), focusing on parenchymal echogenicity, hepatomegaly, calcifications, cirrhosis, and masses. Although capturing the left and right portal veins and GB in a single frame is challenging, practicing probe tilting and tracing from the right subcostal position (**Fig. 1I**) is critical. This view enables visualization of all liver segments, except segment 8, and allows the identification of the GB on the medial side. For infants around 2 months old with cholestatic hepatitis, this view helps identify signs of biliary atresia, such as the triangular cord sign and a small GB. Tilting the probe further into the right subcostal area reveals that the inferior vena cava drains into the right, middle, and left hepatic veins. This pattern, resembling that of a rabbit, is often referred to as the bunny sign (**Fig. 1J**). The GB can be visualized from both medial and lateral perspectives, offering a comprehensive approach for evaluating the organ and distinguishing artifacts (**Fig. 1K, L**). Careful examination of the GB and biliary duct is crucial for diagnosing common conditions such as gallstones, cholecystitis, GB hydrops, GB polyps, and choledochal cysts. Additionally, increased bile sludge in neonates may lead to inspissated bile syndrome, which is a potential cause of biliary obstruction, including biliary atresia. Rotating the probe along the right axillary line allows tracing of the right kidney and right liver. From the intercostal position, the probe can capture the right hepatic vein coursing horizontally through the right liver lobe, with the surrounding segments (5, 6, 7, and 8) clearly delineated (**Fig. 1M**). While hepatomegaly can often be detected through simple radiography or palpation, this view helps to assess the liver size and shape relative to the right kidney, providing an additional diagnostic perspective. Beyond hepatomegaly, liver evaluation should include an assessment of the parenchymal echotexture for conditions such as fatty liver, hepatitis, or, less commonly, vascular

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anomalies, calcifications, cysts, or tumors. Coarse echotextures with irregular margins are indicative of cirrhosis. The right kidney should be systematically examined in both long and short axes views centered on the hilum (**Fig. 1N, O**). The kidney is prone to various pathologies, including hydronephrosis, ureteral dilatation, pyelonephritis, renal abscesses, stones, and calcifications, necessitating meticulous observation. Additionally, the kidney often presents with anomalies such as ectopic kidney, atrophic kidney, renal agenesis, or malpositioned structures, such as the renal pelvis. Horseshoe kidney is another anomaly that can be identified using ultrasound. In the right intercostal position, tracing the Y-shaped right portal vein allows visualization of segments 5, 7, and 8 of the right lobe of the liver (**Fig. 1P**). Shifting the probe to the left axillary line reveals the spleen adjacent to the left kidney (**Fig. 1Q**). The spleen typically has a crescent-like shape, and its long axis should approximately match the long axis of the kidney across all age groups. Enlargement of the long axis and overall size of the spleen indicates splenomegaly. The left kidney, similar to the right kidney, should be examined along both the long and short axes (**Fig. 1R, S**). Being closer to the probe, the left kidney can be observed more closely by adjusting the focus and depth settings. This allows for a more detailed evaluation of its structure and function. A transverse scan below the umbilicus provides a comprehensive view of key pelvic structures. From left to right, this includes the right psoas muscle, right iliac artery and vein, urinary bladder, left iliac artery and vein (Doppler), and left psoas muscle (**Fig. 1T**). The mucosal layers of the nearby intestines can be resolved in detail using a high-frequency linear probe. In contrast, a low-frequency convex probe is ideal for assessing deeper structures such as the urinary bladder, rectum, and pelvic cavity. This pelvic view is essential for diagnosing conditions such as cystitis, ovarian cysts, ovarian torsion, and ascites in the pelvic cavity. A systematic approach to visualize the entire urinary bladder and its surrounding structures is particularly important. In the future, transitioning to a high-frequency linear probe after this exercise will prepare patients for advanced intestinal ultrasound training. The urinary bladder serves as a central landmark for identifying surrounding structures, particularly using the right psoas muscle as a reference point. Adjacent bowel loops can be examined using alternating compression and relaxation techniques. The intestinal wall is visualized as a five-layer structure with a characteristic pattern of white lumen, black mucosa, white submucosa, black muscularis propria, and white serosa, forming a distinct linear appearance (**Fig. 1U**). Training to trace the submucosal layer, which appears as a high-echo (white) line, is an essential step in developing proficiency. Identifying the cecum first is an efficient approach because it often contains stool, making it more recognizable. Depending on the stool consistency, the distal mucosa may not always be visible. Longitudinal tracing of the cecum reveals the characteristic haustral markings of the colon. The terminal ileum can be distinguished by its slightly thicker mucosa and less prominent folds compared with other segments of the small bowel. Locating the ileocecal valve connecting the cecum and terminal ileum is another valuable practice point. Visualization of the terminal ileum and cecum is crucial for diagnosing intussusception, a common pediatric disease. For ileocecal intussusception, a target-like mass with a diameter greater than 3 cm and detectable blood flow on Doppler imaging is considered safe for reduction, with a minimal risk of perforation. Smaller masses (<3 cm) are more likely to represent small-bowel intussusception, which generally requires observation rather than intervention. Precipitating factors for intussusception, such as enlarged lymph nodes, polyps, or tumors, can be identified by closely examining the internal components of the mass. The appendix lies deeper than the terminal ileum and is often located near the psoas muscle. Unlike the ileum, the appendix has relatively no peristalsis and typically measures less than 5 mm in overall diameter. Its position varies widely and may not always be detectable during examination. However, training to distinguish the static

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nature of the appendix from that of the mobile ileum is crucial for identifying or ruling out appendicitis. When appendicitis progresses to the point at which surgical intervention is considered, the appendix typically shows significant ultrasonographic findings. The diameter increases, and the inflamed appendix becomes non-compressible under probe pressure, often eliciting pain. Additionally, mucosal edema and increased vascularity are common and sometimes accompanied by appendicoliths. The surrounding signs of inflammation, such as inflammatory fluid and fat infiltration, may also be visible. Interestingly, diseased bowel segments often appear more prominent and are easier to identify because of these pathological changes. In pediatric patients, multiple lymph nodes are normally observed near the terminal ileum, appearing as black oval-shaped structures of varying sizes. These findings should be carefully differentiated from pathological findings. In the upper abdomen, the transverse colon can be visualized below the stomach (**Fig. 1V**). This segment is more easily identified when filled with stool. Owing to its movable nature, the transverse colon can be manipulated by applying compression or shifting the probe. Detailed examination of the bowel wall is an advanced technique that forms the core of intestinal ultrasound. Normal bowel wall thickness in children, measured from the mucosal layer to the muscularis propria, is typically 2-3 mm or less. Pathological findings may include wall thickening, wall thinning, loss of peristalsis, pneumatosis intestinalis, increased vascularity, diverticula, luminal dilatation, cysts, tumors, polyps, and signs of inflammation, such as inflammatory fluid or fat infiltration. In the left upper quadrant, it is usually possible to visualize a collapsed jejunum with prominent folds and the descending colon (**Fig. 1W**). In the left lower quadrant, the left psoas muscle serves as a landmark to trace the surrounding sigmoid colon (**Fig. 1X**). The colon is characterized by the lack of folds and the presence of haustral markings, with a wall thicker than that of the small bowel. Prominent submucosal and muscular layers are distinguishing features, and stool-filled segments are even more distinct.

CONCLUSION

The author proposed 22 standard views as a foundational learning framework for pediatric abdominal ultrasound training. This structured approach aimed to familiarize all pediatric residents with ultrasound equipment during training. Upon completing their resident training, pediatricians will be equipped to use POCUS effectively across various clinical settings: as a screening tool for pediatric abdominal diseases in primary care, for diagnosing emergency conditions such as intussusception or appendicitis in the emergency department, and for performing advanced hepatic or intestinal ultrasound examinations in tertiary care centers. This framework was designed to empower clinicians to seamlessly integrate POCUS into their practice, tailored to their specific clinical environments.

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