Journal of Medical Ultrasonics (2019) 46:399–412
https://doi.org/10.1007/s10396-019-00954-2

REVIEW ARTICLE–PEDIATRICS

Common pitfalls and mistakes in pediatric ultrasound

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Received: 18 March 2019 / Accepted: 16 May 2019 / Published online: 26 June 2019
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Abstract
There are many errors and pitfalls that are commonly encountered during ultrasound examinations. In normal ultrasound, pitfalls may arise from anatomic or physiologic variants of pediatric anatomy, settings, artifacts, patient conditions, operator misunderstanding, or inexperienced performance. In limited field and point-of-care ultrasound, common errors are usually due to limited access, misdiagnosis as a result of wrong timing, unsuitable patient conditions, limited transducer options, satisfaction of search, and unfamiliarity with pediatric sonography. Knowledge of these pitfalls helps improve a physician's performance and diagnosis.

Keywords Radiology · Ultrasonography · Pediatrics · Artifacts

Introduction

Ultrasound (US) is one of the most important imaging modalities in pediatric radiology. It has been used for screening, diagnosis, and guiding treatment. In pediatric imaging, US is the preferred modality because it does not carry ionizing radiation, provides excellent resolution, is performed in real time, and is easily accessible. Although US is widely used in the pediatric age group, not all sonographers and radiologists are familiar with performing US in children. Since US is operator-dependent, it is essential to understand and recognize common artifacts, mistakes, and pitfalls that may be encountered as these may cause misdiagnoses with significant impact on patient treatment and well-being.

This article discusses the common errors in normal US and limited field or point-of-care US (POCUS) (Table 1). The article describes details of each pitfall or artifact, the underlying physics, and how to recognize them. We also offer problem-solving approaches and include some illustrations of typical phenomena.

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Sources of errors in normal US

Pitfalls associated with normal anatomy/variations in children

Junctional parenchymal defect versus cortical scar

The junctional parenchymal defect is a variation in fusion of fetal renunculi or lobules, which may mimic cortical scars (Fig. 1). It can be seen as a thick, triangular, echogenic notch at the anterosuperior or posteroinferior aspect of kidney and may be connected to the renal hilum by an echogenic line called the "inter-renuncular septum" [1].

Solution: junctional parenchymal defects and remnants of renunculi are located between renal pyramids; while renal scars are at the cortex overlying renal calices with thinning of the parenchyma (the calices are often clubbed and dilated).

Dromedary hump versus renal mass

A "dromedary hump" is caused by splenic impression, visualized as a focal bulge along the lateral aspect of the left kidney (Fig. 2) [1].

Table 1 Categories of commonly encountered mistakes and pitfalls

In normal ultrasound
Pitfalls associated with normal anatomy/variations in children
- Junctional parenchymal defect vs. cortical scar
- Dromedary hump vs. renal mass
- Prominent column of bertin vs. renal mass
- Hyperechoic neonatal cortex with prominent pyramids vs. renal parenchymal disease or caliceal distension/renal cystic disease
- Transiently increased echogenicity of renal pyramids vs. nephrocalcinosis
- Normal brain of premature infant vs. lissencephaly
- Physiologically larger ventricles in preterm infants on brain US
- Physiologic cavi in neonates vs. arachnoid cyst
- Coarctation of frontal horn vs. cystic periventricular leucomalacia
- Superior cervical extension of thymus vs. neck mass
Pitfalls associated with device settings/artifacts
- Pseudothrombosis
- Side-lobe artifact and slice-thickness artifact vs. pseudosludge
- Wrong dynamic range leading to a missed lesion or pseudo-lesion
- Inappropriate settings vs. true perfusion defect of the renal parenchyma
- Mirror artifact vs. true structure
- Exaggerated renal length from refraction artifact
- Missed small renal stones using spatial compound imaging technique
Pitfalls associated with patients' condition
- Position-induced variation in size of transverse sinus or cerebral ventricles
- Clumping of the nerve roots from position
- Inadequate hydration vs. resolved urinary tract dilation
- Dilated collecting system in a fully distended bladder vs. true pelvicaliceal dilatation
- Collapsed gallbladder in non-fasted children vs. small gallbladder in biliary atresia
Pitfalls associated with misunderstanding/performance
- Physiologically hyperechoic white matter vs. periventricular leukomalacia
- Lobular choroid plexus vs. germinal matrix hemorrhage
- Linear vs. curved transducer in detailed imaging
- Inaccurate angle assessment due to tilted access/wrong perspective
- Double collecting system or dilated calyces vs. cysts
- Cystic lesion vs. missed aneurysm or pseudoaneurysm
In limited field ultrasound and POCUS
Limited field/accessible area
Misdiagnosis due to wrong scanning period
Unsuitable patient condition
Limited transducer options
Satisfaction of search
Unfamiliarity with pediatric sonography

Solution: the "dromedary hump" has the same echogenicity as the adjacent renal cortex, whereas a renal mass often has an appearance different from the renal parenchyma, often disrupts normal cortico-medullary differentiation, regionally bulges the outer renal contour, and may cause a mass effect on central structures [2].

Prominent column of Bertin versus renal mass

A prominent column of Bertin (hypertrophied column of Bertin, parenchymal bridge) refers to a normal variant, which is a hypertrophic renal cortical tissue, commonly found in the middle of the left kidney (rarer in the right kidney) (Fig. 3). It is located between the renal pyramids and projects into and distorts the renal sinus. It is iso-echogenic to the adjacent renal parenchyma, and sometimes slightly

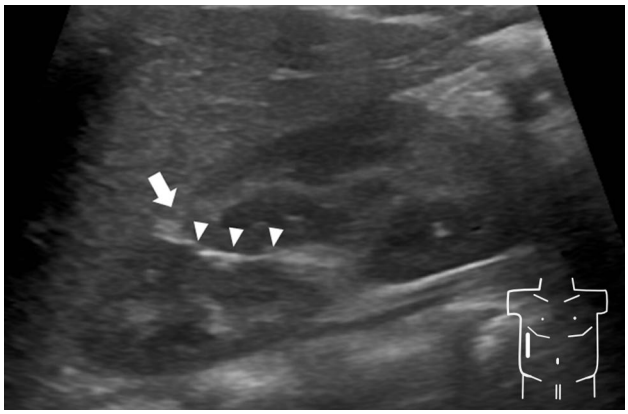

Fig. 1 Echoic notch at the anterosuperior surface of the kidney representing a "junctional parenchymal defect" (arrow) connected to the renal hilum by an echogenic line called the "inter-renuncular septum" (arrowheads). This physiologic remnant can be mistaken as a renal scar

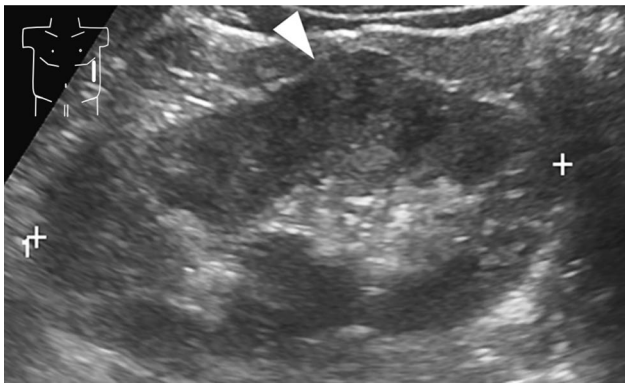

Fig. 2 Focal bulging along the lateral aspect of the left kidney represents a "dromedary hump" (arrowhead), which has the same echogenicity as the adjacent cortex and does not disrupt the cortico-medullary differentiation (+…+renal length)

hyperechoic. Large and prominent columns of Bertin may prompt radiologists to consider an infiltrative renal process.

Solution: prominent columns of Bertin can be confirmed on follow-up scans or on contrast-enhanced cross-sectional studies by showing enhancement similar to the surrounding renal parenchyma and no growth over a short period of time [2].

Hyperechoic neonatal cortex with prominent pyramids versus renal parenchymal disease or caliceal distention/ renal cystic disease

The neonatal cortex is hyper- or isoechoic relative to the adjacent liver (and spleen) parenchyma. It will attain hypoechogenicity by 4–6 weeks of age, and should not be interpreted as renal parenchymal disease. Additionally,

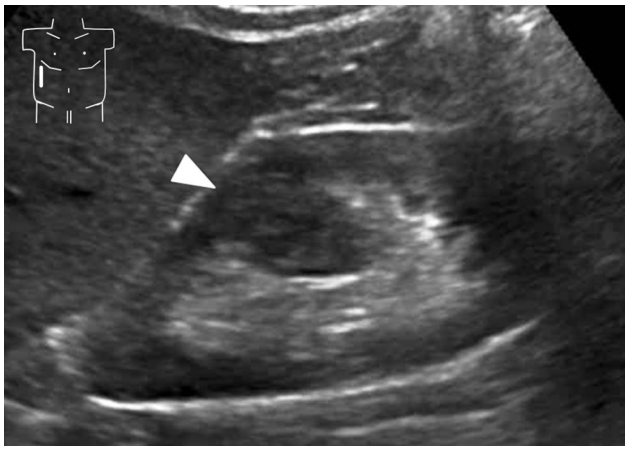

Fig. 3 A mass-like lesion (arrowhead) has the same echogenicity as the renal parenchyma, is located between the renal pyramids, and projects into the renal sinus. It is likely to be a prominent column of Bertin as it did not grow on follow-up scans (image is not shown)

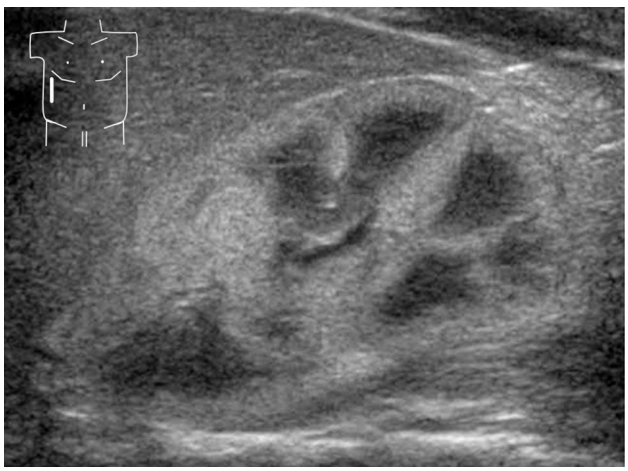

Fig. 4 Hyperechoic renal cortex in a premature newborn with accentuated cortico-medullary differentiation. This is a normal age-specific finding and should not be perceived as renal parenchymal diseases with dilated calices

pyramids may appear relatively large and hypoechoic, causing misinterpretation as dilated calices or renal cystic diseases by those who are unfamiliar with this finding. This usually occurs when low gain and dynamic range with crisp post-processing are used (Fig. 4) [3].

Solution: knowledge of age-specific appearances is an essential requisite for pediatric US, as are proper handling of the device, respective settings, and correct transducer choice.

Transiently increased echogenicity of renal pyramids versus nephrocalcinosis

Transiently increased echogenicity of the pyramids is a common physiologic phenomenon in neonates, with the incidence varying from 3.9 to 58% in healthy neonates [4]. At most, hyperechogenicity can be seen in up to half of the pyramids or only close to papillae. This phenomenon is transient and resolves quickly. The exact cause remains unclear and controversial, but is probably due to some sort of deposition in distal tubules [3]. This finding can be confused with medullary or papillary nephrocalcinosis, and rarely with infection. When in doubt, this finding should be carefully correlated with clinical information and laboratory results (Fig. 5a, b).

Solution: follow-up after hydration and physiological maturation will show spontaneous resolution. However, in patients with poor hydration or under antibiotic and diuretic therapy, these deposits may eventually cause nephrocalcinosis.

Normal brain of premature infant versus lissencephaly

The normal infant brain develops sulcation at 24–40 weeks of gestational age (GA). Parieto-occipital sulci appear at 24 weeks, and cingulate sulci appear at 28 weeks. Further sulcation begins at 30 weeks.

Solution: Lissencephaly should not be diagnosed in children younger than 24 weeks of GA, and delayed maturation must be considered in differential diagnoses [5].

Physiologically larger ventricles in preterm infants on brain US

Preterm infants have larger ventricles (and sometimes frontal and occipital extraaxial spaces) than term infants, which should not be misinterpreted as hydrocephalus. The same applies to a wide frontal extraaxial space in familial macrocephalus, which is a normal variant and self-limited [6].

Solution: normal clinical presentation and stable or decreased degree of dilatation on follow-up examinations likely indicate physiologic changes rather than hydrocephalus. As such, the parenchyma-ventricle ratio is helpful and sometimes better than ventricular size measurement.

Physiologic cavi in neonates versus arachnoid cyst

The cavum septum pellucidum is a cystic space in the septum pellucidum. The cavum vergae is located posteriorly to the level of the fornix. These are normal variants resulting from the failure of fusion of two septal leaves. The cavum velum interpositum is seen as a cyst-like structure at the pineal region. These variants start to close around the 6th month of GA and are mostly closed before 6 months of chronological age [7]. Persistence of these physiologic cavi may be mistaken as an arachnoid cyst (Fig. 6a–d).

Solution: Arachnoid cysts have a mass effect. Physiologic cavi have no mass effect in their specific position. However, arachnoid cysts are benign and usually asymptomatic, so differentiation between these two conditions is usually not crucial.

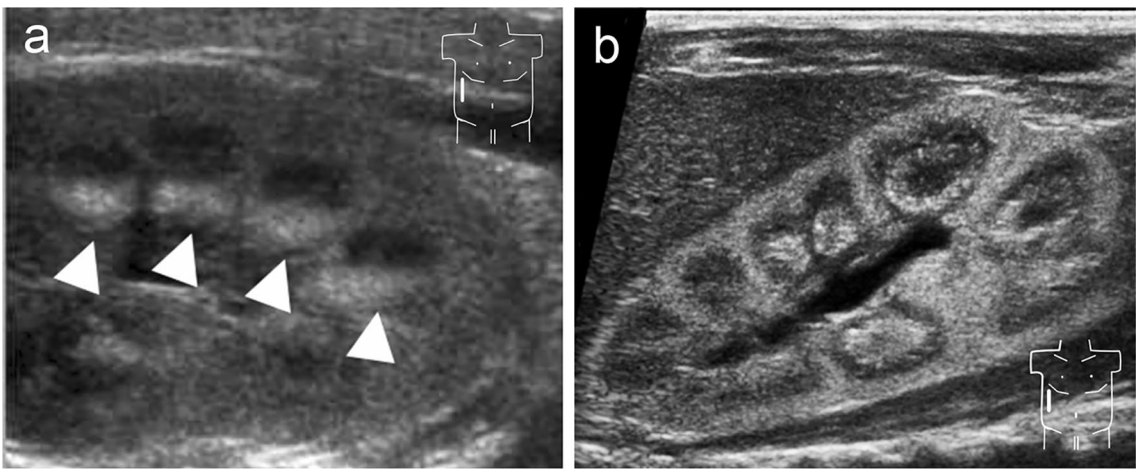

Fig. 5 **a** Transiently increased echogenicity of the pyramids (arrowheads) is a normal finding in a 1-day-old neonate (resolved on follow-up after 7 days; image is not shown)**. b** Early stage medullary nephrocalcinosis in a 4-month-old male with electrolyte imbalance is seen as hyperechogenicity at the peripheral medulla of the right kidney

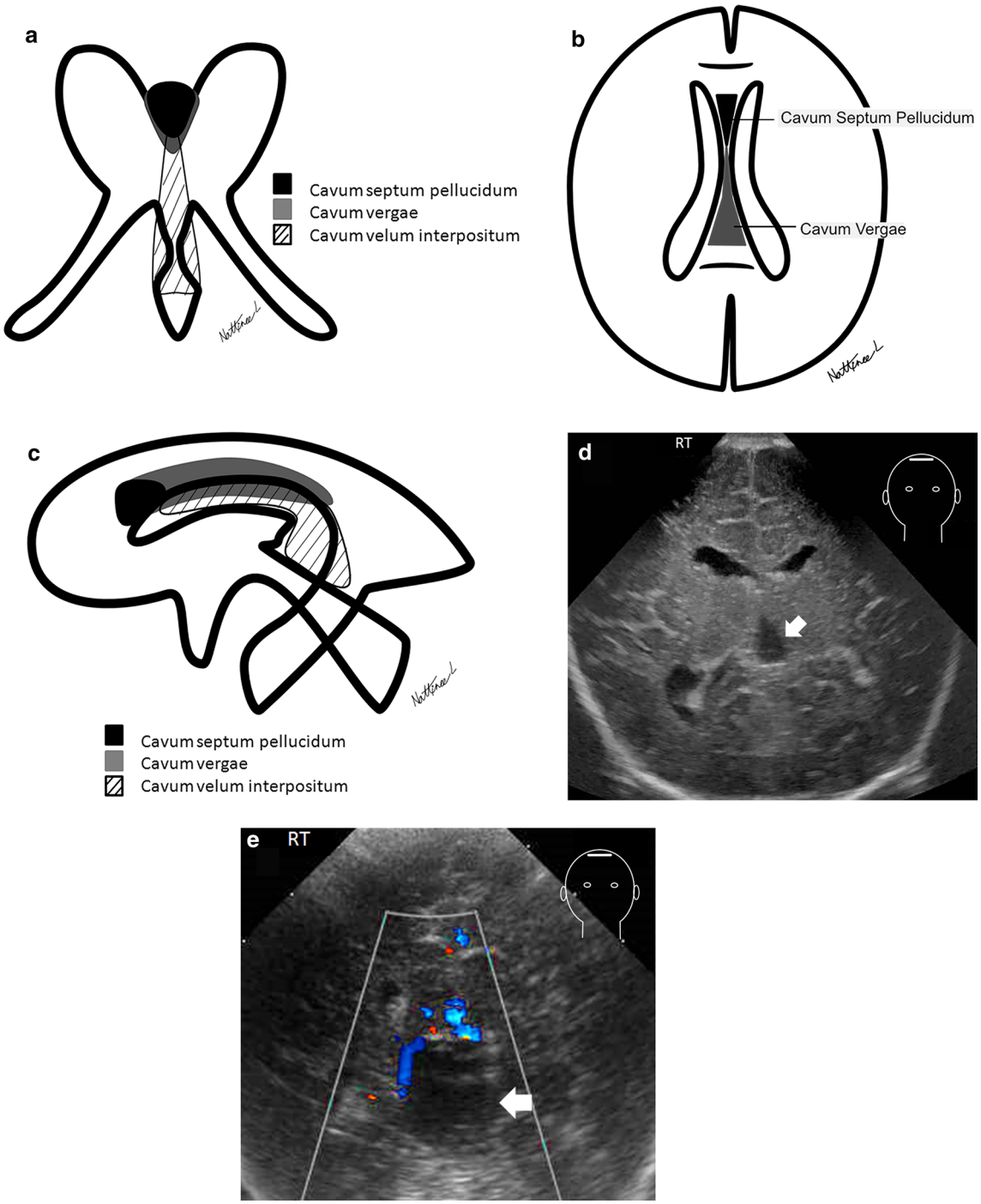

Fig. 6 **a**–**c** The drawing demonstrates locations in coronal (**a**), axial (**b**), and sagittal (**c**) views of caval variants. **d** Neonatal brain US in a coronal view shows a cavum velum interpositum, located below the splenium of corpus callosum. **e** Another neonatal brain US in a coronal section at the level of quadrigeminal cistern demonstrates a 2.1 × 0.8-cm cyst causing lateral displacement of internal cerebral veins, consistent with an arachnoid cyst

Coarctation of frontal horn versus cystic periventricular leukomalacia (PVL)

Connatal cysts (coarctation of the frontal horn, frontal horn neuroepithelial cysts) are normal variants, probably originating by approximation of walls of the frontal horns of lateral ventricles. Diagnosis should not be confused with cystic PVL.

Solution: connatal cysts are located at or just minimally below superolateral borders of the body and the frontal

horns of the lateral ventricles, and mostly anterior to the foramen of Monro, while cystic PVL is above the superolateral angle of the body and the frontal horns of the lateral ventricles (and other periventricular regions) (Fig. 7a–d) [7]. On follow-up examinations, connatal cysts are stable, whereas cystic PVL changes depending on development, severity, and clinical context.

Superior cervical extension of thymus versus neck mass

Cervical extension of the thymus is a normal finding that can be found in more than 60% of children [8]. Sometimes, this condition may be mistaken as a neck mass.

Solution: the normal thymus has fine granularity and a homogeneous echotexture, and it is commonly hypoechoic when compared to the thyroid gland. The cervical part usually continues with and has the same echogenicity and texture as the mediastinal thymus. It also exhibits a smooth contour without a pressure effect on vessels or airways (Fig. 8a, b).

Pitfalls associated with device settings/artifacts

Pseudothrombosis

Normally, children have slower blood flow than adults, which can be erroneously presumed to be thrombosis on color Doppler sonography (CDS), particularly if the sensitivity is too low, the scale is set wrongly, or filters are too high. Additionally, a poor insonation angle (close to 90°) can cause pseudothrombosis.

Solution: pseudothrombosis can be corrected by applying appropriate transducers (for example, using higher frequency transducers), choosing adequate gain and focus

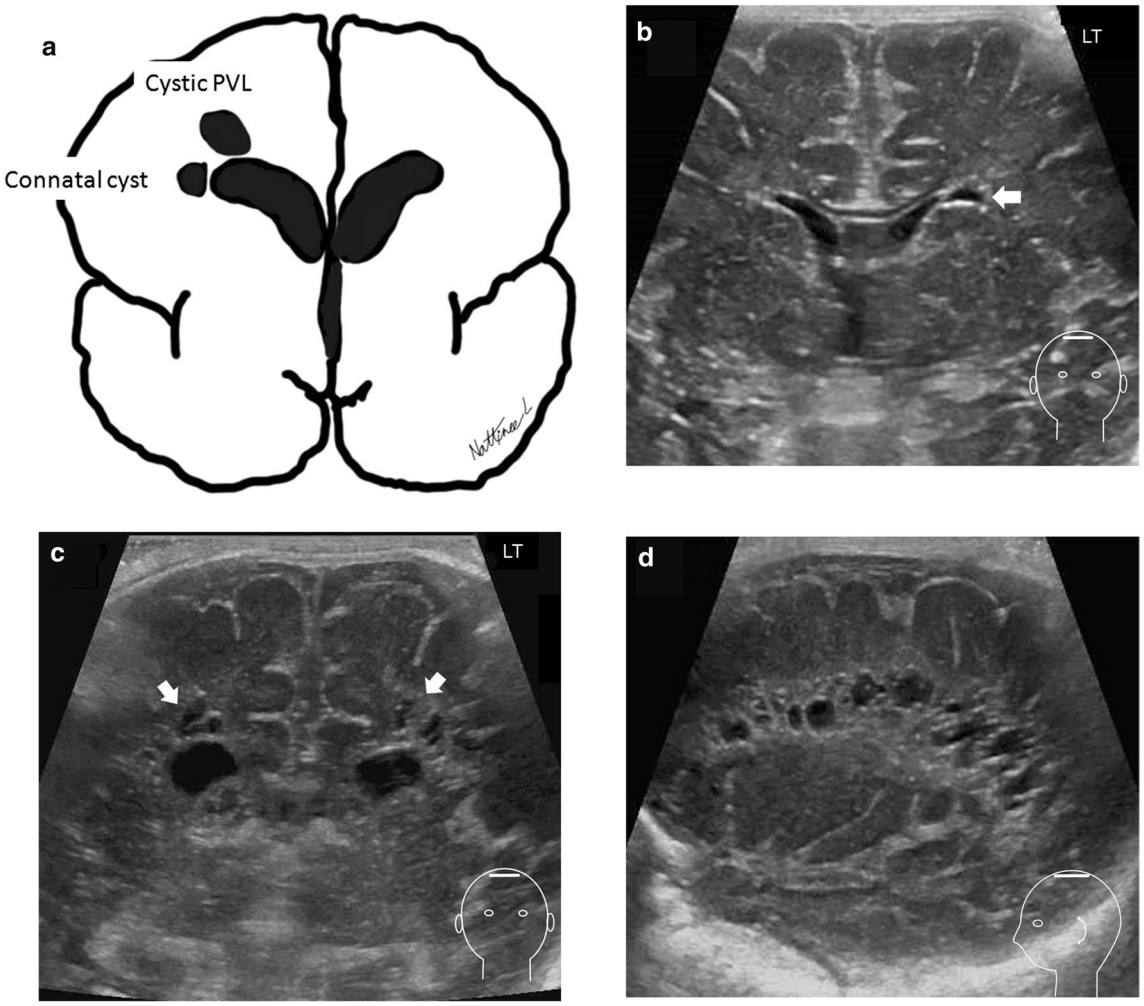

Fig. 7 **a** The drawing shows the location of a neuroepithelial cyst and cystic PVL in a coronal view. **b** Coronal view of neonatal brain US shows a left connatal cyst. **c–d** Coronal view (**c**) and left parasagittal view (**d**) of the preterm neonatal brain reveal bilateral cystic PVL above the superolateral angle of the body of the lateral ventricles, extending posteriorly along the periventricular region and involving the periventricular white matter near the occipital horn

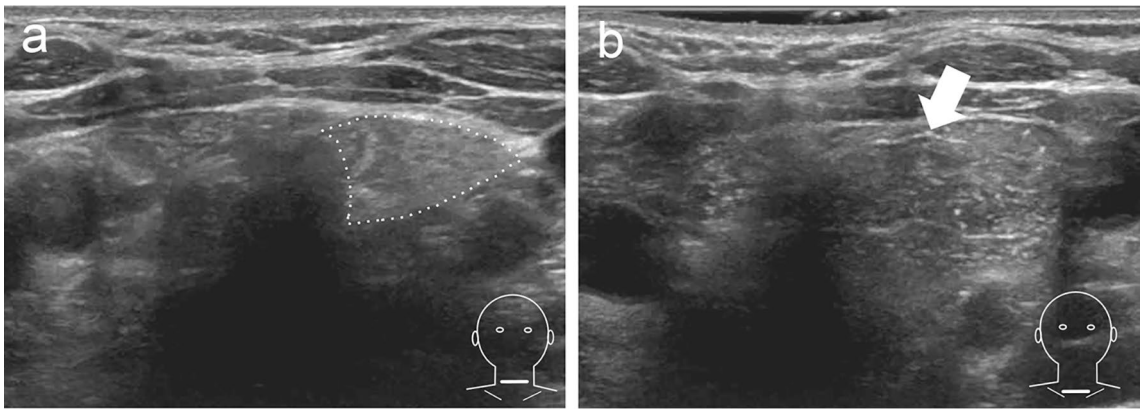

Fig. 8 **a**, **b** Ultrasound of the thymus (axial view) demonstrates cervical extension of the thymus (**a**, dash line) in continuity with the normal thymus (arrow) (**b**)

position, properly adjusting velocity, decreasing wall/noise filters, and using the lowest possible Doppler angle (Fig. 9a, b) [9].

Pseudothrombosis can also be encountered on grayscale US when the examined vessel has slow or sluggish flow. This can be addressed by adapting the gain setting and performing additional (amplitude-coded) CDS.

Side-lobe artifact and slice-thickness artifact versus pseudosludge

Side-lobe artifacts originate from side-lobe beams located peripherally to the main beam. When side-lobe beams hit a highly reflective surface, the beams are consequently displayed as if they have arisen from the main beam. This artifact is accentuated on the background of fluid-filled anechoic structures, which can be seen as low-level echoes within fluid-mimicking sludge, debris, or pus.

Solution: change the insonation angle.

Another important artifact is the slice-thickness artifact due to the partial volume effect of the US beam. This artifact occurs when the beam is too broad in relation to the cystic structure so one part of the beam interacts with the cystic structure and another part interacts with adjacent soft tissue. Examples are pseudosludge in the gallbladder or pseudosedimentation in the urinary bladder (Fig. 10).

Solution: Change the insonation angle, use sufficient US gel (reducing noise that may enhance this artifact), and reduce the output power and gain. Repositioning the patient is also helpful. Moreover, true sludge always layers in the dependent portion and exhibits a flat surface, while pseudosludge may be curved and not in the dependent portion [10].

Wrong dynamic range leading to a missed or pseudo-lesion

The dynamic range is the ratio of the highest and the lowest displayed echo signal levels. US machines often come with presets that use the low dynamic range. However, operators can manually adjust the dynamic range. The high dynamic range provides better distinction of delicate echo differences (more shades of grey), so anechoic structures (for example,

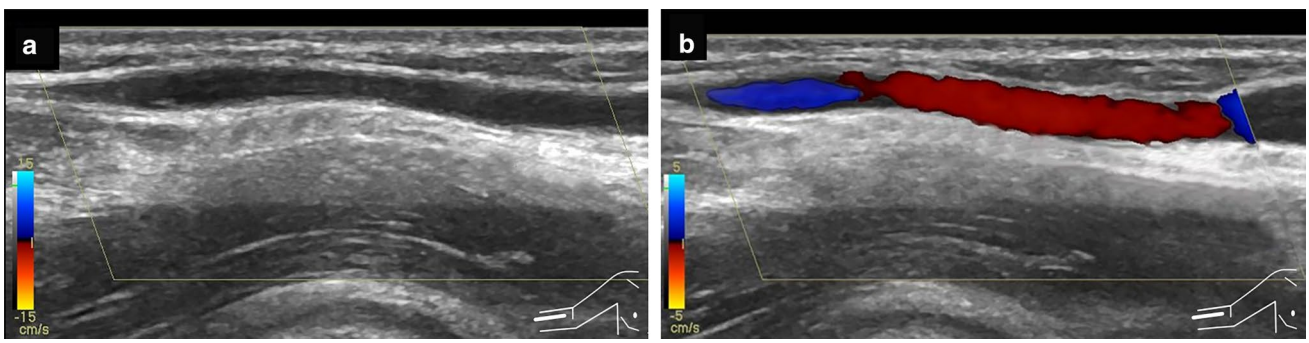

Fig. 9 **a** CDS reveals no flow due to high-velocity setting, leading to suspicion of thrombosis. **b** There is normal color flow in the vessel after correction of the velocity scale

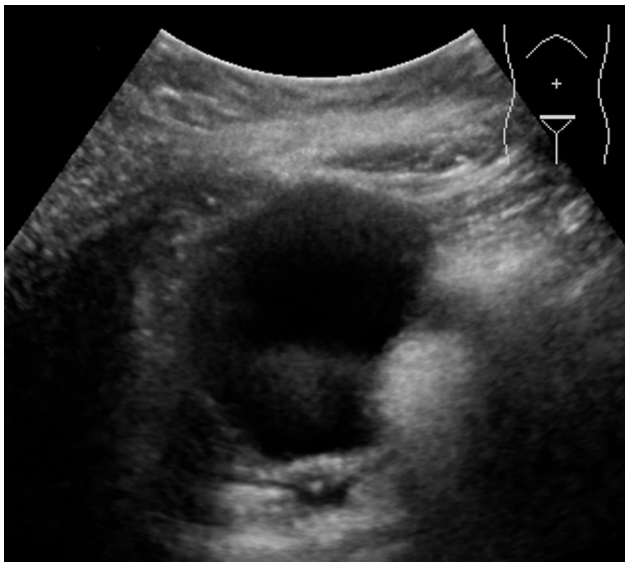

Fig. 10 An echoic area resembles floating sludge in the urinary bladder due to the a side-lobe artifact and too high gain settings. After changing the angle of insonation and adjusting the gain setting, the artifact is resolved (image is not shown)

vessels or gallbladder) may look like they have an internal echo and be misdiagnosed as thrombosis or sludge [11]. In contrast, the narrow/low dynamic range leads to greater discernible echo differences (crisper black and white differentiation). Missing small thrombosis or minimal sludge caused by this effect can cause a false-negative result.

Solution: Use mid dynamic range settings or scan with both high- and low-range settings.

Inappropriate settings versus true perfusion defect of the renal parenchyma

Renal parenchyma, especially in the periphery, may exhibit reduced or no blood flow on CDS when operators inappropriately adjust the settings (for example, when using a poor insonation angle at high filter settings). This area may be misinterpreted as a renal scar or focal pyelonephritis.

Solution: Like pseudothrombosis, re-evaluation after adjusting the settings is helpful. Adequate hydration also helps reduce the risk of artificial peripheral perfusion defects.

Mirror artifact versus true structure

Gas and bone reflect the US beam and may act as acoustic mirrors in the body. Therefore, mirror artifacts are common in all areas with gas or bone and soft tissue interfaces, especially between lung and liver (or spleen). The mirrors of the hepatic or splenic parenchyma may be misdiagnosed as pulmonary lesions such as pneumonia or diaphragmatic hernia or even tumors (Fig. 11a–c).

Solution: Change the insonation angle [10]. Note that this phenomenon applies not only to basic grayscale US but also to CDS and may create confusing images by mirroring directional color encoding.

Exaggerated renal length from refraction artifact

The speed of sound in human soft tissue and fat is approximately 1540 m/s and 1450 m/s, respectively. These differences may result in a refraction artifact, commonly seen as duplication of deep structures by beam refraction from superficial structures. For example, the sound refracts the liver and fat interface when scanning the kidney, causing duplication of the upper pole. The artifact leads to erroneous renal length measurement (Fig. 12a, b).

Solution: the access should be changed [10].

Missed small renal stones using spatial compound imaging technique

Image compounding acquires multiple frames with different frequencies (frequency compounding) or different angles (spatial compounding). Acquisitions are then combined to form a single compounding image [12]. Spatial compounding reduces shadow artifacts by insonating the same area from different angles and averaging an effective displayed image signal. This may be a disadvantage when diagnosing small stones as shadow artifacts may aid identification.

Solution: Turn off spatial compounding to retrieve better images. Harmonic imaging may improve tissue contrast and acoustic shadow definition.

Pitfalls associated with patients' condition

Position-induced variation in size of transverse sinus or cerebral ventricles

When a newborn brain is imaged in the lateral decubitus position (or head turned), the sinus and the ventricle may look asymmetrical. This finding should not be misinterpreted as transverse sinus hypoplasia/stenosis or undersized ventricle. An explanation for this phenomenon may be the effect of gravity or compression of the draining jugular vein by positioning [13].

Solution: Re-examine in another position.

Clumping of the nerve roots from position

Clumping of the spinal nerve roots can occur when an infant is scanned in the lateral decubitus position, then potentially mistaken as true clumping or pseudomass.

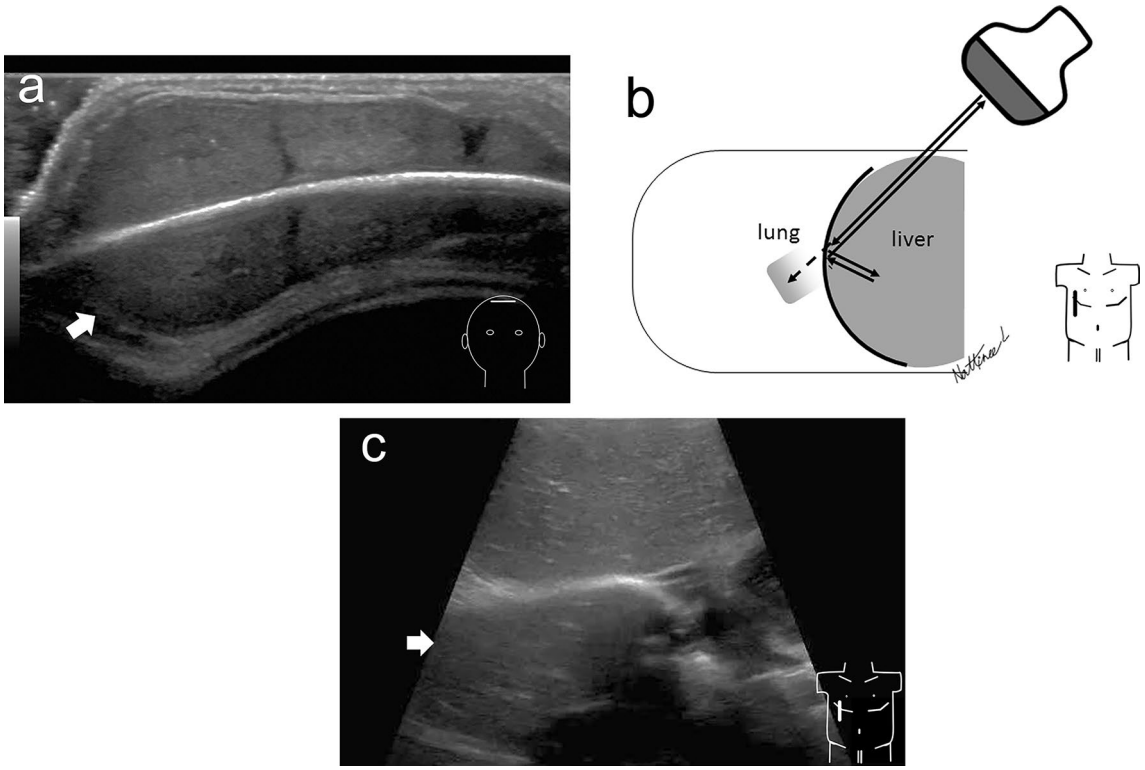

Fig. 11 **a** Mirror artifact at the scalp-skull interface, causing duplication of a scalp hemangioma (arrow) potentially being misinterpreted as an intracranial lesion. **b** The drawing shows generation of the mirror artifact. The ultrasound beam reflects at the lung-diaphragm interface and travels back to the liver parenchyma, causing a false echo in the lung field. **c** Duplication of the hepatic parenchyma at the interface between lung and liver/diaphragm (arrow), which may be misdiagnosed as pneumonia

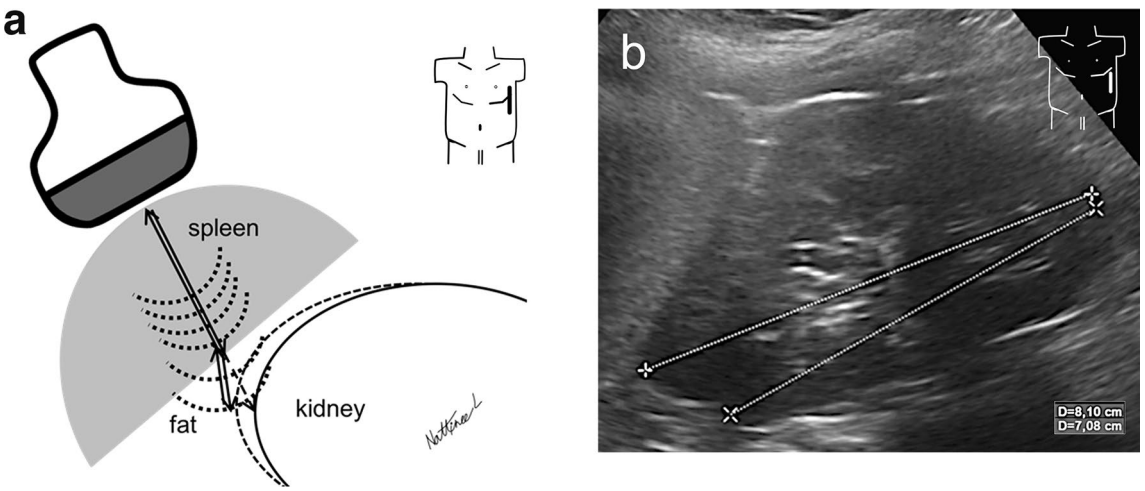

Fig. 12 **a** The drawing demonstrates refraction of the sound beam when passing from the spleen (faster speed of sound) to fat (slower speed of sound), resulting in duplication of the upper pole of the left kidney. **b** A refraction artifact of the upper pole of the left kidney causes an artifactually exaggerated renal length

Solution: Re-examine the patient in the prone position [14].

Inadequate hydration versus resolved urinary tract dilation

Often, the urinary tract is assessed to search for urinary tract dilatation (UTD). However, sufficient urine output and

bladder filling are essential for assessment of the dilated collecting system or else the collecting system may collapse and mask the dilatation.

Solution: radiologists should be cautious when diagnosing the collapsed or less dilated urinary tract in inadequately hydrated patients as improved or resolved UTD. Postnatal urinary tract US for UTD should be performed after the first postnatal week to allow renal maturation and adequate urine production (unless there is some other urgent condition). In addition, standardized hydration is vital for proper recognition and grading of UTD, and also important for comparison during follow-up [4].

Dilated collecting system in a fully distended bladder ("Bladder Phenomenon") versus true pelvicaliceal dilatation

Occasionally, when the patient has a fully distended bladder, pelvicaliceal (and ureteral) dilatation can be seen. This condition should not be mistaken as pathologic UTD.

Solution: This dilatation is temporary and can be resolved after voiding (Fig. 13a, b). A similar phenomenon can sometimes be observed in hyperhydration or diuretic stress or in a compensatory single kidney. Additionally, vesicoureteral reflux may cause the same phenomenon.

Collapsed gallbladder in non-fasted children versus small gallbladder in biliary atresia

When infants inadequately abstain from food or drink, the gallbladder can be collapsed and seem to be small. This finding can be confused with a small gallbladder in infants with biliary atresia.

Solution: re-examination after allowing patients to have adequate fasting time improves gallbladder distension, and furthermore other signs may indicate the underlying condition (Fig. 14a, b).

Pitfalls associated with misunderstanding/performance

Physiologically hyperechoic white matter versus periventricular leukomalacia

Hyperechoic white matter may appear as a pseudo-lesion adjacent to the ventricle. This tends to be more prominent in premature infants and is normally less echogenic than the adjacent choroid plexus. It occurs due to an anisotropy effect. Additionally, unspecific edema or white matter immaturity may cause a similar appearance.

Solution: an orthogonal orientation, using linear transducers, and follow-up help discriminate this normal condition from PVL or hemorrhage [5].

Lobular choroid plexus versus germinal matrix hemorrhage

The choroid plexus is seen as a smooth hyperechogenic structure usually located in all ventricles. A choroid plexus with lobulation can be mistaken as a germinal matrix hemorrhage, especially when located near the caudothalamic groove.

Solution: in the lateral ventricles, the choroid plexus never spreads frontally beyond the level of the caudothalamic groove, whereas a germinal matrix hemorrhage situates at the caudothalamic groove. One may find vessels in the choroid plexus on CDS, whereas a hemorrhage does not

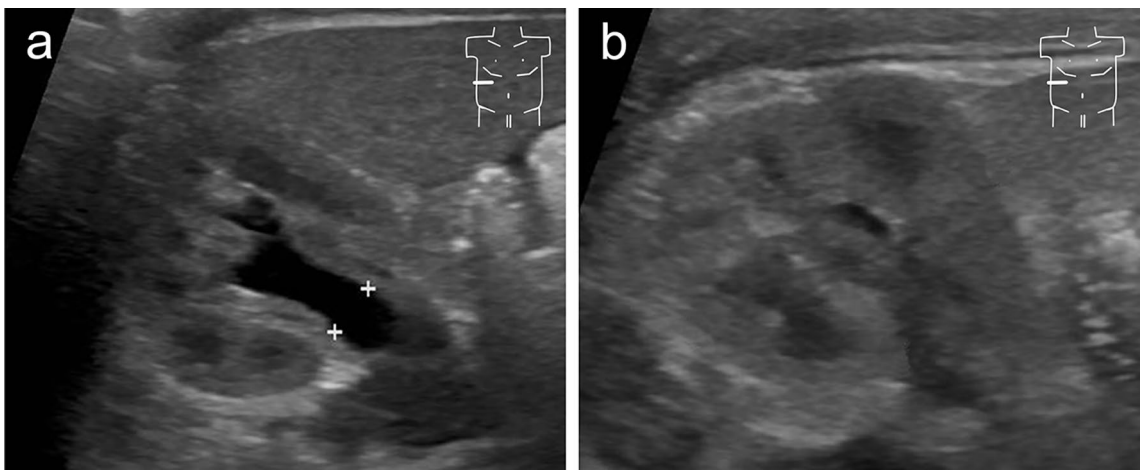

Fig. 13 **a** Axial view of the distended renal pelvis (+ … +) in a child with prolonged fully distended bladder. **b** After voiding the dilatation resolved

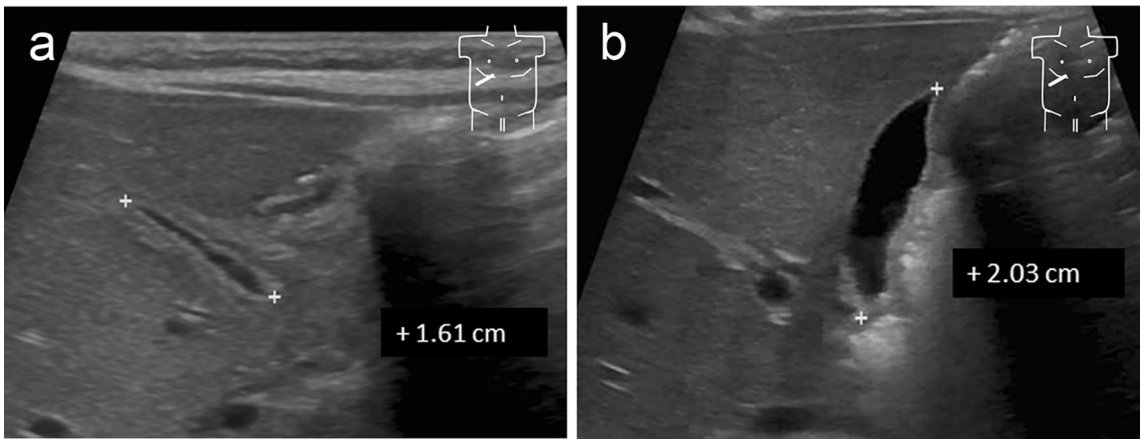

Fig. 14 A 1-month-old neonate presenting with jaundice. **a** Small collapsed gallbladder after 1-h fasting. **b** Re-examination after 6-h fasting results in good distension of the gallbladder

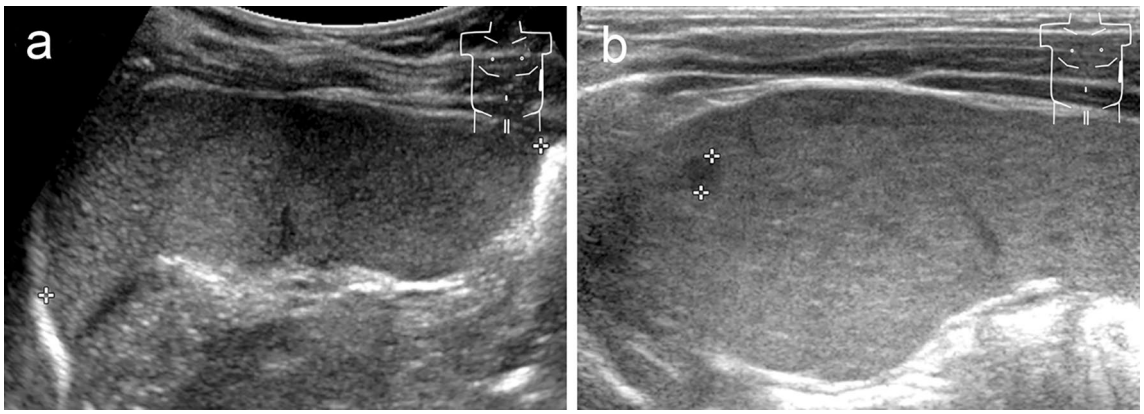

Fig. 15 A case with Melioidosis infection. **a** A 5-MHz curved transducer image shows no splenic lesion. **b** A 12-MHz linear transducer image reveals a small hypoechoic lesion, probably a splenic microabscess

have internal vascularity. Furthermore, the choroid plexus remains unchanged on follow-up.

Linear versus curved transducer in detailed imaging

Abdominal US is mostly performed with a curved transducer to access a larger image range. In some case, however, the curved transducer results in missing small lesions such as small abscesses (Fig. 15a, b).

Solution: Re-scanning using linear transducers offers more detailed images.

Inaccurate angle assessment due to tilted access/wrong perspective

A good example to illustrate this artifact is US for congenital hip dysplasia using the Graf method. In hip US, sections with a tilted transducer will lead to wrong angle measurements and thus a wrong diagnosis. This may apply to other structures, as well (Fig. 16).

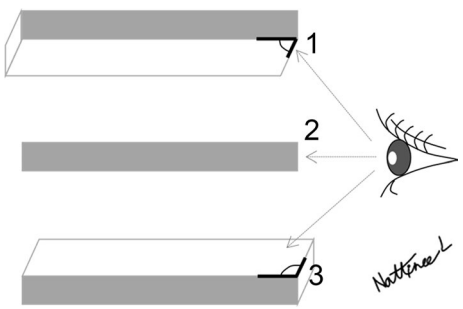

Fig. 16 The drawing illustrates inaccurate angle assessment using improper perspective (1, 3)

Solution: Image in the appropriate plane and check if angles and perspective are adequate.

Double collecting system or dilated calyces versus cysts

In a complete double collecting system, the upper pole system is more likely to be obstructed than the lower pole (Weigert-Meyer rule), resulting in the dilated pelvicaliceal system of the upper moiety. A huge cystic dilatation of the upper moiety with thin residual parenchyma should not be mistaken for a renal cyst [1, 4]. Another situation that may mimic renal cysts is severe pelvicaliceal distention. Additionally, calyces or medullae of the kidney scanned at the low dynamic range may accentuate cortico-medullary differentiation and appear cyst-like (Fig. 17).

Solution: meticulously search for additional findings such as dilated renal pelvis or ureter and a peripherally located parenchymal rim. Adapting the dynamic range will assist the diagnosis of urinary tract dilatation.

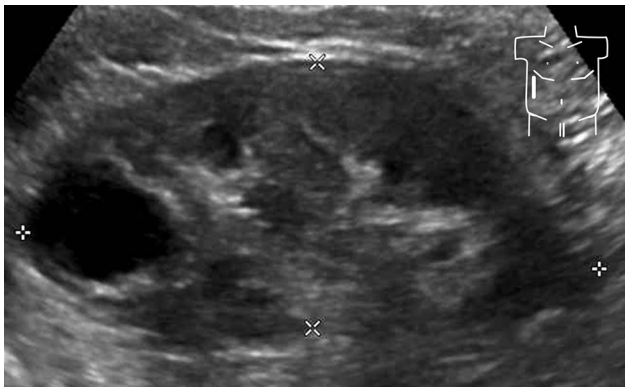

Fig. 17 Focal dilated calyces may be misinterpreted as a cyst

Cystic lesion versus missed aneurysm or pseudoaneurysm

An anechoic cyst-like lesion might not always be only a simple cyst. For example, a pancreatic "cyst" may be a splenic artery pseudoaneurysm, or a choledochal cyst may be a portal vein (or hepatic artery) aneurysm [15].

Solution: identify vessels and use CDS in every case to ensure that the cystic lesion is not an aneurysm or pseudoaneurysm, particularly if the location is atypical or occurs after an intervention (Fig. 18a, b).

Pitfalls in limited field and point-of-care ultrasound (POCUS)

Limited field/accessible area

In postoperative or post-traumatic patients, small accessible areas for transducer positioning may cause limitations. This may result in underestimating the extent of a lesion or missing the lesion in inaccessible regions.

Solution: Try to get rid of any unnecessary material obscuring the scanning field and change patient position or access plane. However, sometimes this restriction is inevitable and other imaging modalities may be more suitable.

Misdiagnosis due to wrong scanning period

Knowledge of temporal evolution of findings is essential. For example, US may not depict hemorrhage in the hyperacute stage, particularly in the liver or the spleen, because hyperacute hematoma and parenchyma have the same echogenicity. Another example is early vascular injury of the

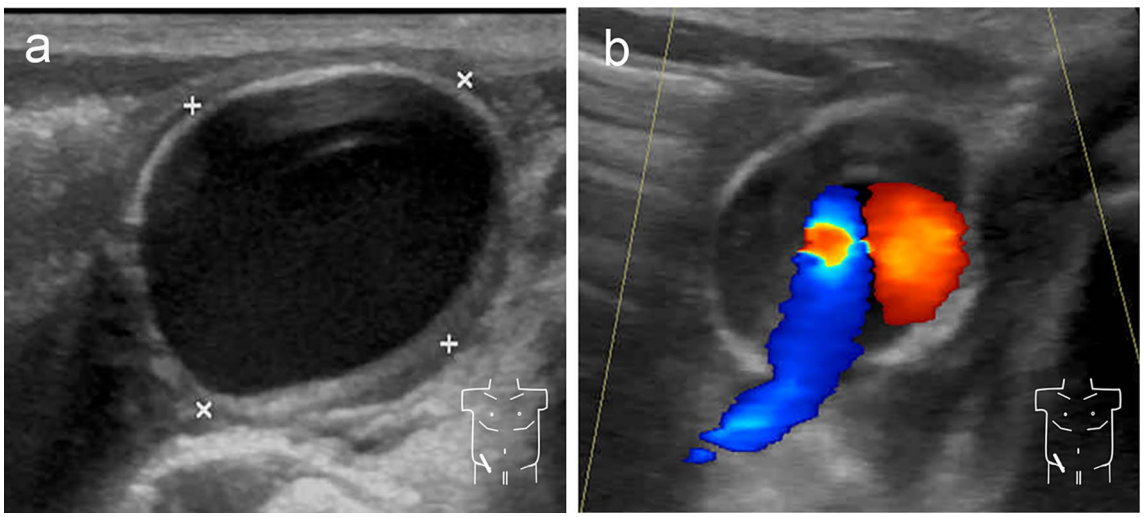

Fig. 18 A child after coronary angiography for 2 days. **a** Grayscale US of the pelvis shows a well-defined anechoic cyst. **b** CDS reveals internal flow in the cystic lesion, likely a pseudoaneurysm of the right external iliac artery

kidney, which makes the kidney look normal on grayscale US.

Solution: follow-up imaging and correlation with clinical information may be helpful. CDS or contrast-enhanced US may be essential under such conditions.

Unsuitable patient condition

The patient's condition or the requested queries may not be suitable for the US examination. For instance, in unstable patients, the operator may hurriedly terminate the examination even though the diagnosis has not yet been established.

Solution: Do not deviate from performance standards by employing rushed scanning and making potentially wrong or incomplete diagnoses. If necessary, communicate the restrictions to the clinicians.

Limited transducer options

There may be limited transducer availability such as no high-frequency and high-resolution transducers needed for children. This will lead to loss of image details and limited visualization of some structures and may cause a false-negative result.

Solution: If this situation is unavoidable, explain limitations and consequences to the clinician and/or the patient. Other alternative modalities may be considered.

Satisfaction of search

Satisfaction of search happens when the operators stop the examination after they discover one abnormality and are satisfied with the finding. In other words, the investigation is ended prematurely. This commonly occurs when examiners are biased by clinical expectations. However, there may be other undiscovered abnormalities that may change or affect the diagnosis or may be essential for management decisions.

Solution: try to perform the examination systematically using a checklist of the various organs and structures that should be explored.

Unfamiliarity with pediatric sonography

Anatomy and conditions in children differ from adults. For example, what looks like a severe renal parenchymal disease in the adult is a normal appearance of the neonatal kidney (Fig. 4).

Solution: knowledge, practice, and experience help the operator get used to pediatric age-adapted imaging appearance. As such, appropriate US education (and licensing) for pediatric scanning is essential.

Conclusion

Radiologists and sonographers should be aware of possible and sometimes correctable phenomena, pitfalls, artifacts, some physiologic conditions, anatomical variants, etc. In addition, recognizing them and knowing possible solutions will help to achieve good image quality and avoid misdiagnosis. Knowledge of these phenomena that everyone may encounter in daily pediatric US is vital and can only be obtained through experience and education in pediatric sonography. Nevertheless, there are still inevitable limitations and errors, especially in the limited field and POCUS. Awareness and knowledge of these pitfalls and carefully performing the US examination will help reduce misreading and increase the conspicuity of US results.

Compliance with ethical standards

Conflict of interest Nattinee Leelakanok and Panruethai Trinavarat declare that they have no conflicts of interest. Michael Riccabona received honoraria and travel compensation from US companies (Siemens, GE) and a contrast agent company (Bracco) within 36 months, and is also involved in equipment improvement and protocol development for many ultrasound vendors and contrast agent companies. However, these have no impact on this article.

Ethical statements All ultrasound exams were performed in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and later versions. Informed consent was obtained from all patients who underwent ultrasound. Images were retrospectively used with institutional approval. No identifying information of patients is included in the study.

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