Acute abdomen in pediatric radiology

Das akute Abdomen in der Kinderradiologie

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Key words
volvulus, pediatric, acute abdomen, appendicitis, ovary, newborn

published online 22.12.2023

Bibliography
Fortschr Röntgenstr 2024; 196: 451–462
DOI 10.1055/a-2193-0205
ISSN 1438-9029

Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

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ABSTRACT

Background Imaging is a common part of the workup for acute abdomen in childhood and adolescence. Rapid diagnosis is crucial for adequate therapy, especially in young children.

Method This review is intended to provide an overview of the typical causes of acute abdomen in children and adolescents and is specifically aimed at radiologists who do not regularly work in pediatric radiology.

Results and Conclusion Age-specific peculiarities make a division into three age groups useful: Newborns, infants and toddlers, and schoolchildren. Possible causes of acute abdomen in children range from congenital lesions, particularly in newborns, to entities well known in adult radiology, more commonly in school-aged children. Since younger children have a higher sensitivity to radiation and often a limited ability to cooperate, sonography and conventional X-ray are the primary imaging modalities used. Decisive advantages of sonography, especially in younger children, include its widespread availability, the lack of need for sedation, and the possibility of bedside examination. Supplementary cross-sectional imaging, usually MRI, is reserved for special clinical questions. Close interdisciplinary cooperation between attending clinicians and radiologists is essential for efficient diagnostics in this patient group.

Key points:
- Age-specific features must be observed
- Sonography and radiography are the most important modalities
- Both congenital and acquired pathologies play a role
- Good interdisciplinary cooperation is essential in this patient group

Citation Format
- Lochbühler N, Bölle P, Müller-Abt P. Acute abdomen in pediatric radiology. Fortschr Röntgenstr 2024; 196: 451–462

ZUSAMMENFASSUNG

Hintergrund Im Kindesalter kommt es häufig zur Bildgebung beim akuten Abdomen. Mit diesem Artikel soll ein Überblick über die häufigsten Differentialdiagnosen und die Zuordnung zu den Altersklassen Neugeborene, Säuglinge und Kleinkinder sowie Schulkinder gegeben warden.

Methode Zusammenfassende Übersicht über die Bildgebung beim akuten Abdomen von Neugeborenen, Säuglingen, Kleinkindern und Schulkindern unter Berücksichtigung der aktuellen Literatur.

Ergebnisse und Schlussfolgerung Altersspezifische Besonderheiten machen eine Aufteilung in drei Altersgruppen sinnvoll: Neugeborene, Säuglinge und Kleinkinder sowie Schulkinder. Mögliche Ursachen für ein akutes Abdomen reichen von angeborenen Läsionen insbesondere bei Neugeborenen bis zu aus der Erwachsenenradiologie bekannten Entitäten vorwiegend beim Schulkind. Aufgrund eingeschränkter Kooperationsfähigkeit und höherer Strahlensensitivität stehen insbesondere bei jüngeren Kindern Sonografie und Röntgen an erster Stelle bei der bildgebenden Diagnostik. Die rasche Verfügbarkeit, fehlende Notwendigkeit einer Sedierung sowie Möglichkeit der Untersuchung am Patientenbett ist gerade bei jüngeren Kindern ein entscheidender Vorteil der sonografischen Diagnostik. Ergänzende Schnittbilddiagnostik, in der Regel MRT, ist speziellen Fragestellungen vorbehalten. Eine enge interdisziplinäre Zusammenarbeit zwischen betreuenden Klinikern und Radiologen ist für eine effiziente Diagnostik in dieser Patientengruppe unabdingbar.

Introduction

Acute abdomen is a very common reason for presentation to the emergency department, particularly in the case of children. The following article aims to provide an overview of important aspects of the topic for radiologists – in particular for radiologists who are only occasionally confronted with pediatric radiology cases. The clinical evaluation of the abdomen during childhood, and in particular in young children, is complicated by the fact that children are often unable to adequately express their complaints. As a result, every "stomach pain" in the child or adolescent has a certain degree of "acuteness", and imaging plays an important role. Due to age-specific characteristics, the subdivision into three different age groups appears sensible: neonates, infants and toddlers, and school age children. From adolescence onwards, adult medicine diagnoses must be incorporated into the differential diagnostic considerations. Trauma-related causes of acute abdomen are not included in this paper. An overview of the different clinical pictures is provided in ▶ **Table 1**.

Neonatal period

The primary symptoms of an acute abdomen in neonates are a distended abdomen and bilious vomiting. Causes of ileus in this age group can be congenital, acquired, or a combined congenital and acquired etiology.

In the neonatal period, both ultrasound and conventional X-ray diagnostics and bowel fluoroscopy with contrast media (usually water-soluble) are used for the diagnosis. Abdominal X-ray (AB) is often the first diagnostic imaging tool in neonates with abdominal problems, if necessary supplemented by imaging in the left lateral position [1]. CT and MRI examinations are not applicable to this age group. Fluoroscopy should be performed with adequate collimation, pulsed, and using 'last image hold'. Gastrointestinal tract and colon contrast enemas are administered [1]. Transient hypothyroidism has been described in premature babies and neonates after the administration of iodinated contrast media [2]. In our clinic, thyroid levels are therefore followed up 7–10 days after the administration of contrast media.

Necrotizing enterocolitis (NEC) is the most common and most serious disease in the neonatal period. It mainly affects physiologically immature preterm infants [3]. NEC is the most common pediatric gastrointestinal surgical emergency in preterm infants [4] and most frequently occurs at 14 to 21 days of age [5]. There is an increased risk of developing ileus adhesions and short bowel syndrome [4]. Clinical symptoms manifest in the form of feeding difficulties, vomiting, distended abdomen with pressure pain, and possibly bloody stool. The abdominal skin is bluish or reddened [3]. Dilated, distanced intestinal loops, intramural gas, gas in the portal vein, and free air in pneumoperitoneum can be seen on abdominal overview radiograph (▶ **Fig. 1a–c**) [6]. Ultrasound is more sensitive in experienced hands than X-rays [3].

Ultrasound may identify

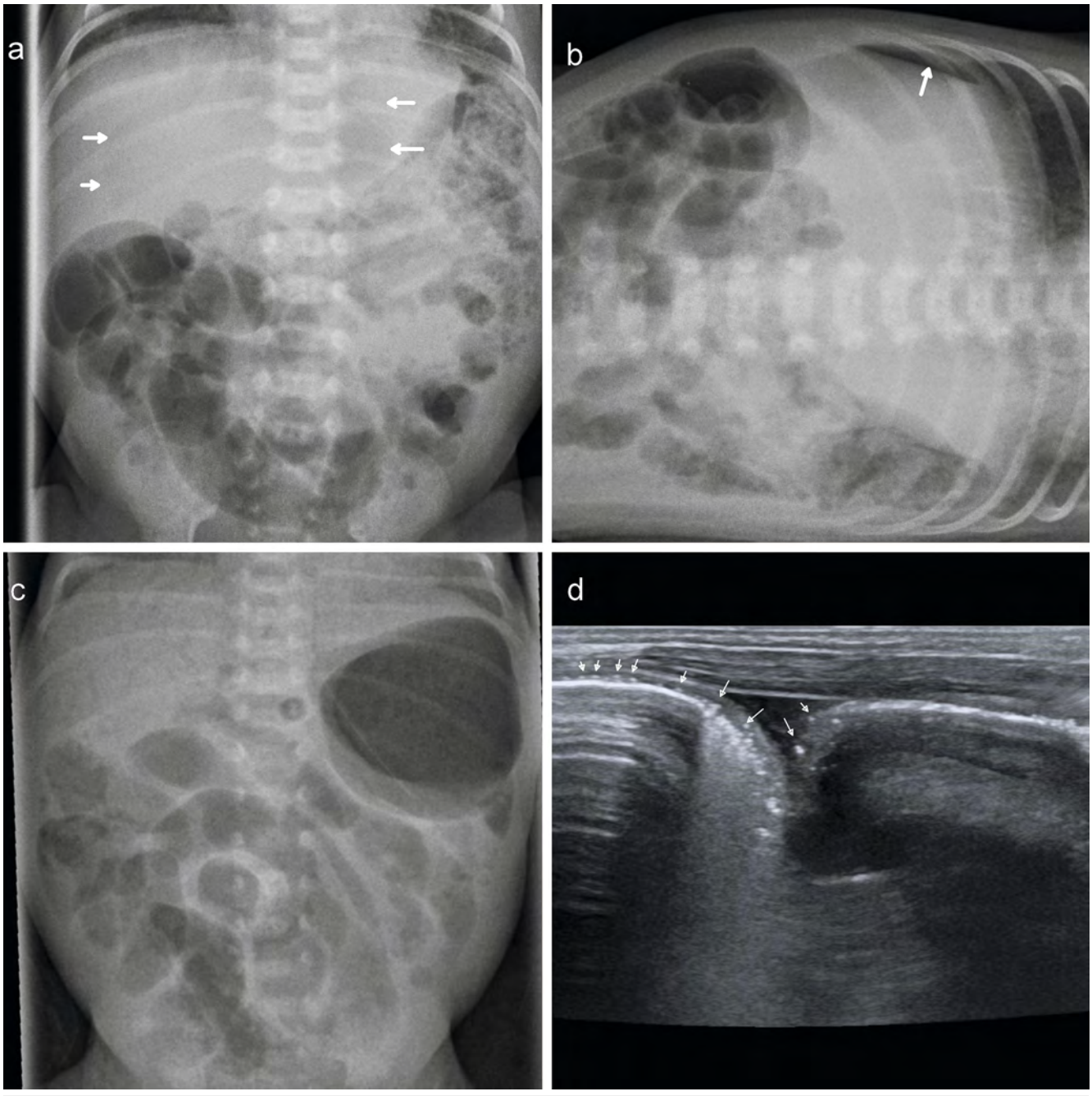
- largely hyperechoic bowel walls
- intestinal wall thickening (> 3 mm)
- thinning of the intestinal wall
- dilated intestinal loops
- the absence of peristalsis
- intramural gas in the form of increased echogenicity of the intestinal wall (▶ **Fig. 1 d**)
- focal hyperperfusion or the segmental absence of perfusion
- increased flow velocity in the mesenteric vessels
- decreased flow velocity in the portal vein
- mobile punctate echogenic enhancements on B-scan, short bidirectional spikes on spectral Doppler superimposed on normal portal vein flow.

A colon contrast enema is not indicated, especially in NEC [4]. Many complex ascites or air bubbles are suggestive of a perforation [3].

A differential diagnosis is focal intestinal perforation (FIP), which can occur in very physiologically immature preterm babies without signs of inflammation during the first days of life. The perforation site is often localized to the terminal ileum. Clinically, FIP is characterized by sudden onset, livid discoloration of the abdomen, and radiologically by the presence of air bubbles on conventional X-rays [7]. Congenital malformations include **atresia**. Atresia is the most common cause of ileus in neonates. Duodenal atresia results from an absence of canalization [8]. Duodenal atresia manifests as vomiting with or without bilious gastric contents. It occurs pre- or post-papillary. The annular pancreas is a special form. On the X-ray image, it presents as a typical "double bubble sign" (air in the stomach and duodenum in the context of an

▶ **Table 1** Age-related causes of acute abdomen.

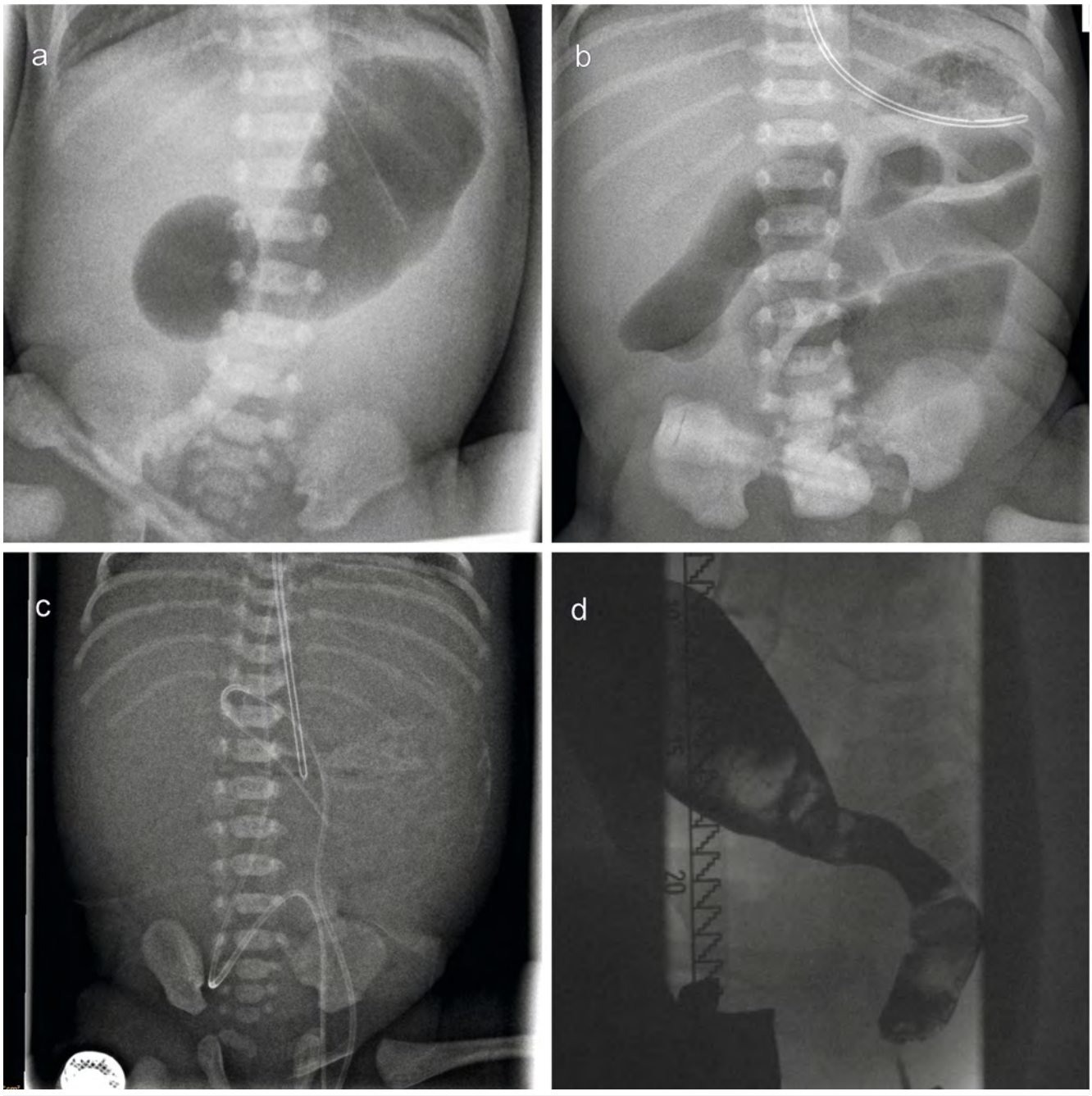
Neonates	Infants/toddlers	School children/adolescents
Necrotizing enterocolitis	Intussusception	Appendicitis
FIP = focal intestinal perforation	Hypertrophic pylorus stenosis	Ovarian torsion
Atresia/stenosis	Ingestion of foreign body	Testicular torsion
Meconium ileus	Meckel's diverticulum	Gastroenteritis
Meconium plug syndrome	Bowel duplications	Cholecystitis
Hirschsprung's disease	Basal pneumonia	Pancreatitis
Volvulus		



▶ **Fig. 1 a, b** premature baby 33 + 6 weeks. **a** In the right upper abdomen paramedian with bilateral involvement corresponding to free gas ("football sign" arrows) in NEC. **b** X-ray in left lateral position (arrows). Free gas above the liver **c** Premature baby 27 + 2 weeks. Tubular branched air formations projected onto the liver corresponding to gas in the portal vein system, i. e., pneumatosis hepatis in NEC. **d** Premature baby 34 + 3 weeks. Hyperechoic reflexes in the intestinal wall in pneumatosis intestinalis (arrows).

otherwise gas-free abdomen) (▶ **Fig. 2a**) [1]. If it is caused by a duodenal membrane, air can be observed in the intestine in addition to the double bubble. Small intestinal atresia is a consequence of intrauterine infarcts, volvulus, or intussusception [8]. In small intestinal atresia, conventional radiography shows a distended stomach and dilated small intestinal loops without air in the colon (▶ **Fig. 2b**). The microcolon can also be seen by sonography. In the context of atresia, anal atresia may also result in ileus.

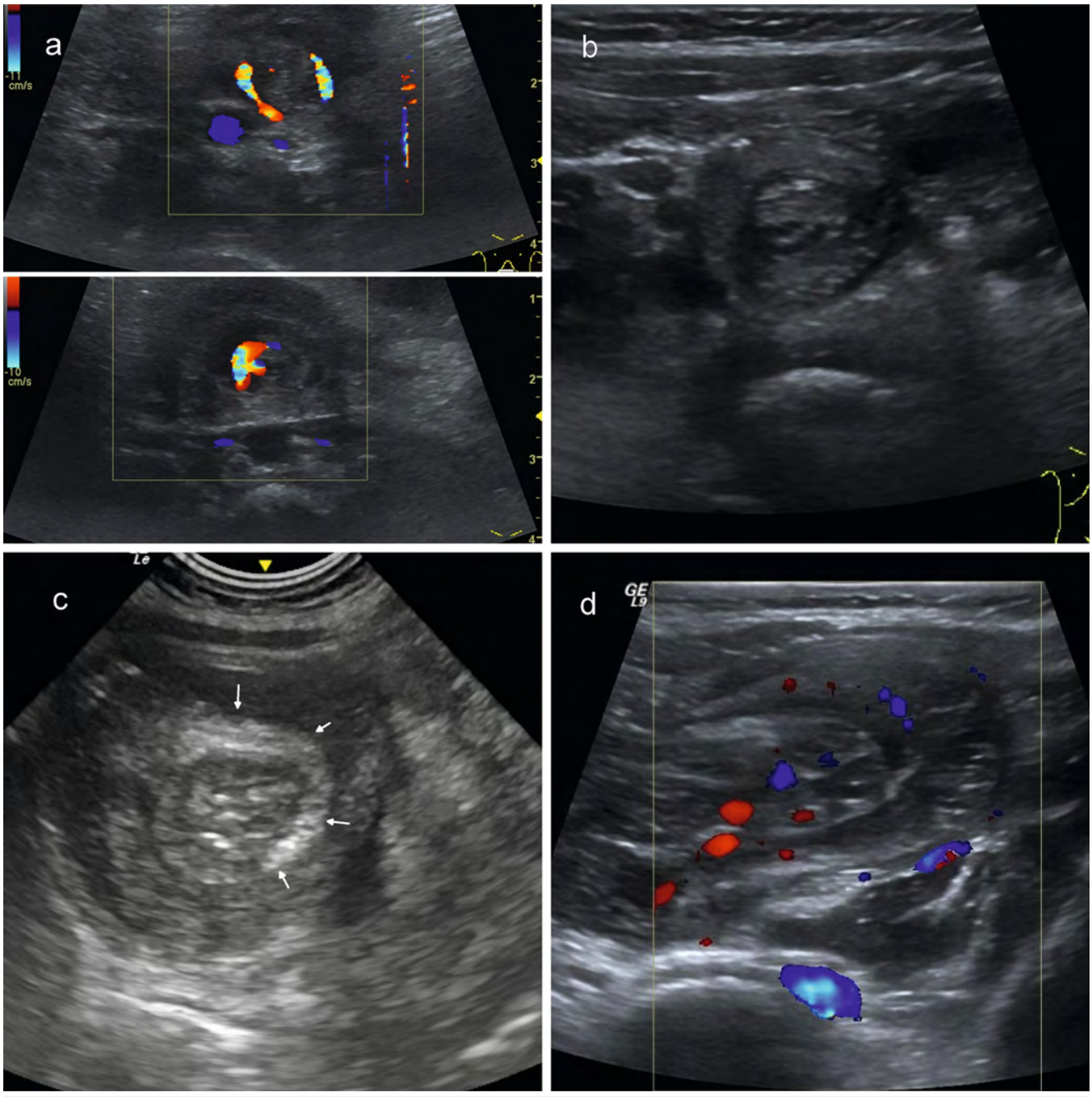
Meconium ileus is caused by thickened meconium in the distal ileum. Cystic fibrosis is causative in 80–90 % of cases [9]. Abnormally hard and sticky meconium leads to a retention of meconium into the significantly enlarged proximal ileum. By sonography, a normal wide terminal ileum can be seen, filled with a homogeneous mass, dilated in the oral direction, also filled with meconium, an atone ileum, and a narrow colon. The microcolon can also be visualized by means of a colon contrast enema; this often also allows the terminal ileum to be flushed out. The cause of



▶ **Fig. 2** **a** Mature newborn, first day of life. Double bubble with air in the stomach and duodenum in the annular pancreas. **b** Premature baby 36 weeks. Stomach slightly filled with air when the gastric tube is in place, proximal small bowel loops dilated, no air in the colon. Small bowel atresia. Additional findings: Umbilical clamp projected **c** Premature baby 33 + 6 weeks, first day of life. Almost gas-free abdomen with reduced transparency and discrete calcifications in meconium peritonitis. NB: Malposition of umbilical vein catheter with half-loop formation. **d** 1 year and 5 months. Constipation since beginning complementary feeding. Colon contrast enema. X-ray in left lateral position. Narrowed, aganglionic rectosigmoid, transition zone and prestenotic dilatation in Hirschsprung disease.

meconium plug syndrome is immature bowel function [1]. A dense meconium plug in the descending colon and rectum leads to the clinical picture of a deep intestinal obstruction. There is no spontaneous meconium excretion. In contrast to meconium ileus, the colon is filled. In this case, the colon contrast enema is both diagnostic and frequently also therapeutic. Meconium peritonitis (▶ **Fig. 2c**) is a consequence of intrauterine intestinal perforation.

Hirschsprung's disease is an aganglionosis of the myenteric and submucosal plexus in a segment of the distal bowel of varying length with consecutive permanent contracture and narrowing of the bowel. The process of meconium excretion is delayed. 80 % of affected individuals present with anomalies during the neonatal period [1]. The diagnosis is made by fluoroscopy with a colon contrast enema. Here we can see the distally narrowed segment, the



▶ **Fig. 3** **a** Newborn. Transverse color Doppler upper abdomen. “Whirlpool sign” by twisting of the mesenteric root (different position). **b** 13-month-old child. Transverse mid-abdominal sonography. Small target sign in ileoileal intussusception. **c** 8-month-old infant. Transverse sonography of the right lower abdomen. Persistent vomiting. Dehydration, later bloody stools. Pathological intestinal target sign in ileocolic intussusception. “crescent in doughnut” sign – corresponding to mesenteric fatty tissue (arrows). **d** 12-month-old child. Transverse mid-abdominal sonography, longitudinal section of invaginate showing perfusion on color Doppler.

transition zone, and the prestenotic enlarged colon (▶ **Fig. 2 d**). The radiological diagnosis and exact extent should be verified by rectal suction biopsies.

Combined congenital and acquired ileus etiologies include volvulus and bowel duplications. “Midgut” **volvulus** generally occurs during the neonatal period, most commonly during the first week of life [1], but can also manifest later. It is caused by abnormal positioning of the bowel. The incompletely rotated and atypically fixed bowel has a small mesenteric adhesion. This carries the risk of torsion of the bowel, the mesentery, and the superior mesenteric vein surrounding the superior mesenteric artery, with narrowing of the vessels. The obstruction arises from an extrinsic peritoneal adhesion, from the midgut volvulus, or a combination of both [1]. The X-ray can show normal or nonspecific gas distribution in the stomach and intestine, but also a double bubble as a sign of duodenal obstruction. Distended intestinal loops may

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▶ Video 1

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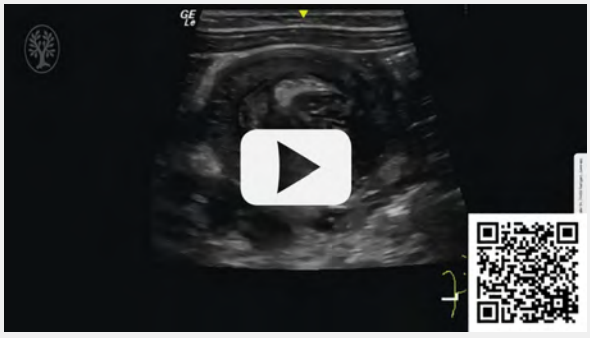


▶ Video 2

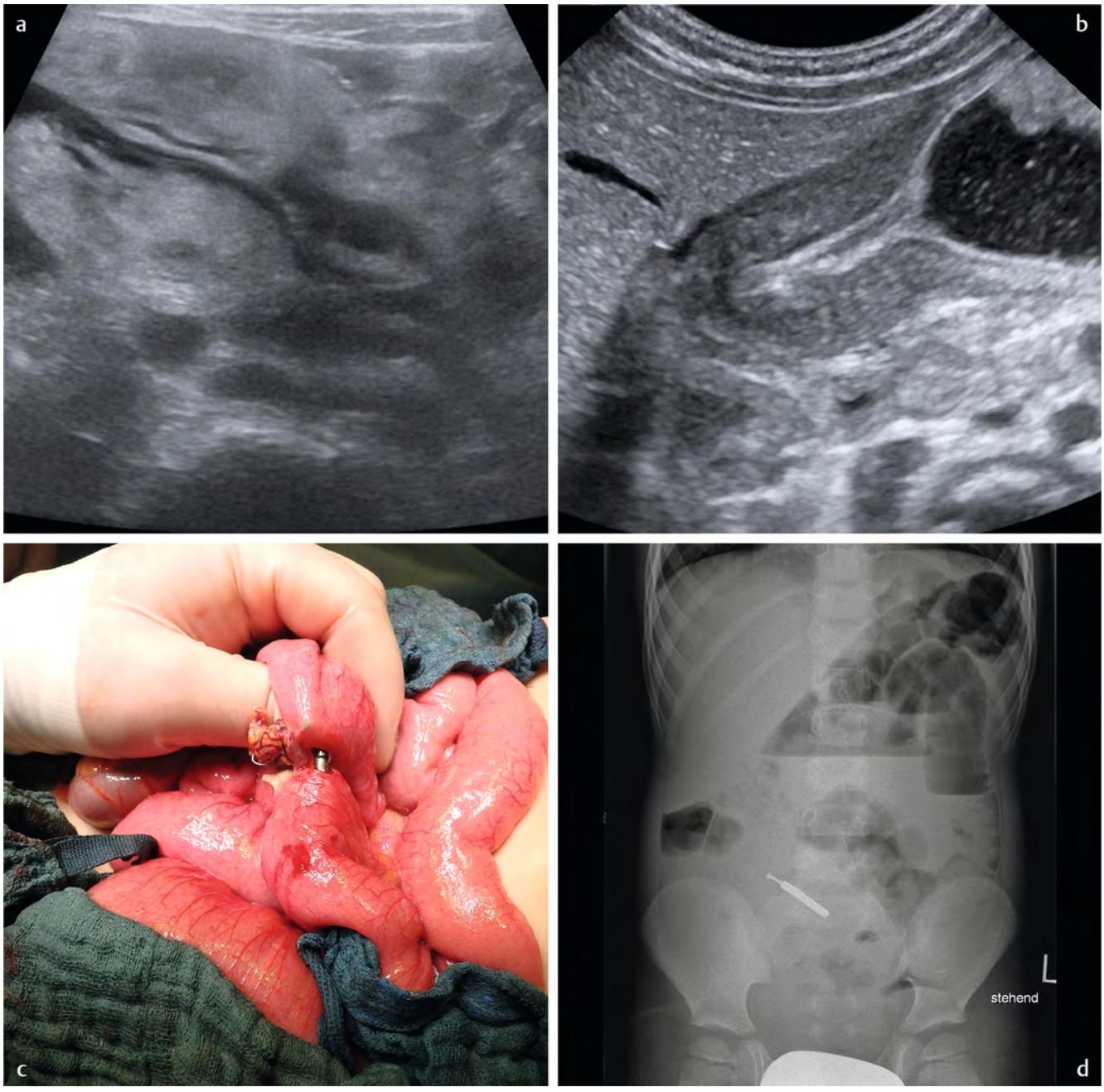
also occur in the context of decreased perfusion. Ultrasound reveals a whirlpool sign at the level of the mesenteric root with atypical locations of the artery and superior mesenteric vein (▶ **Fig. 3a**, ▶ **Video 1**). Persistent ischemia results in loops of thickened small intestinal wall packed closely together in the mid-abdomen devoid of peristalsis. In terms of the gastrointestinal tract, the stomach and proximal duodenum are dilated. Distal to the obstruction, a corkscrew-like contrast enhancement is observed [1]. In general, ultrasound is the first choice examination method as a rapid bedside or emergency room examination method. The feasibility of reconstituting the continuity of the gastrointestinal tract needs to be investigated or established immediately depending on the patient's condition.

Another cause of an acute abdomen is an **incarcerated inguinal hernia**. Ultrasound can detect intestinal loops in the inguinal canal of boys. The hernial sac can extend into the scrotum. In girls, the ovary may prolapse in addition to the bowel. High-resolution sonographic examination may provide evidence of ischemia of the herniated contents, if appropriate.

Infants and toddlers

An **intussusception** is the most common abdominal emergency in children younger than two years of age. Classic symptoms include: spasmodic pain, bloody stool, palpable mass (found only in approximately 50 % of all cases but in 80–90 % of children younger than 2 years of age) [10]. It generally involves an ileocolic intussusception, commonly following a viral infection, and there is a suspected causal association with pathological intestinal motility and enlargement of lymph nodes or Peyer's patches. Other forms of intussusception are rarer and most commonly involve small intestinal intussusception (▶ **Fig. 3b**); These forms are usually transient, and often occur in the context of gastroenteritis. Ultrasound evidence of the typical cocard phenomenon has a very high sensitivity and specificity (▶ **Fig. 3c, d**, ▶ **Video 2**) [11]. Further imaging is generally not required; If perforation in particular is suspected, an abdominal overview image is required to exclude free intra-abdominal gas accumulation (the prolapse may be visible as a dense soft tissue mass). The reduction procedure is usually image-guided either by fluoroscopy or increasingly by sonography in recent decades. Hydrostatic reduction with a saline solution warmed to body temperature is used most frequently (pneumatic reduction has the disadvantage of reduced clarity, particularly with respect to successful monitoring). In our clinic, together with colleagues from the pediatric surgery department, even in the case of a longer medical history (as long as there is no evidence of perforation), a reduction procedure is attempted. We perform this with analgesia, but without sedation (disadvantages of sedation: extra time and personnel required for monitoring, potential complications) [12]. Even a partial reduction makes it easier to perform any additional operation. The reduction procedure is invariably performed under fluoroscopic guidance (pneumatic or with water-soluble contrast media); Safety and the effectiveness of both methods is equivalent [13] – the main disadvantage compared to ultrasound is the use of ionizing radiation. As in other cases, the method used should be the one that the examiner is most familiar with. After a successful reduction, a sonographic follow-up is necessary as up to 10 % of recurrences occur within 24 hours of the reduction procedure [14, 15]. In children older than 3 years of age, investigating a causal pathology is warranted. A pathological lead point is often identified in these cases e. g., Meckel's diverticulum, intestinal duplication, polyps, and lymphoma [12] (▶ **Fig. 4a**). In Henoch–Schönlein purpura, intussusceptions (predominantly small intestinal intussusceptions) have been described as a result of intestinal wall hemorrhage [16].

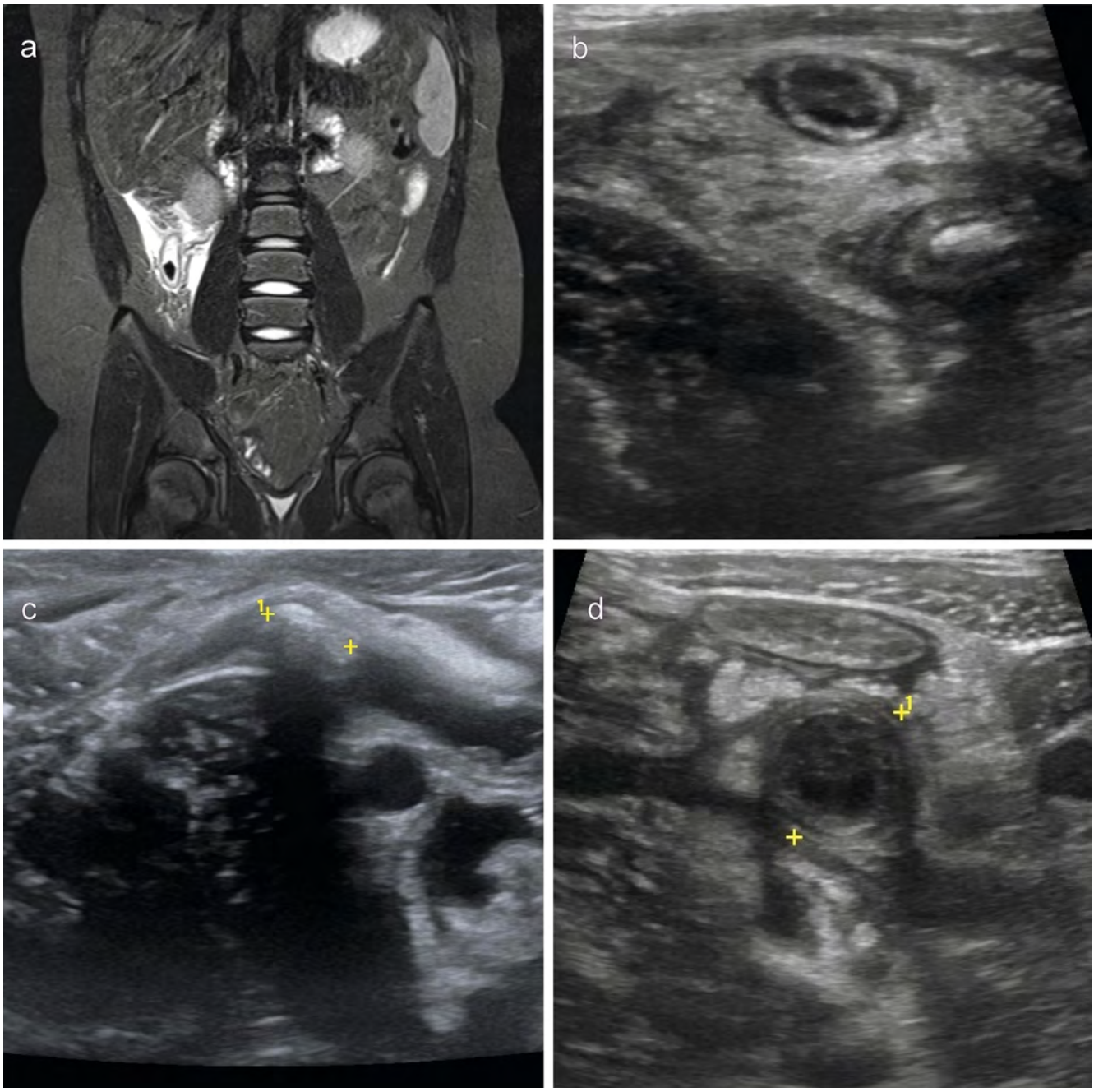
Non-bilious vomiting in an infant between 3 and 6 weeks of age (also observed in premature neonates, even in later infancy) is a classic presentation for **hypertrophic pyloric stenosis**. Weight loss and dehydration occur if the disease is left untreated, and in the longer term a palpable mass can form in the upper abdomen. The incidence in boys is significantly higher than in girls (4–5: 1). Ultrasound is the imaging gold standard [17]. With some experience, the pylorus in the infant can be reliably imaged [18]. If gastric air interferes in the pyloric region, imaging from a right-sided position is generally successful. If this is not the case, the stomach can be used as a sound window after the administration of a clear liquid. The thickened and elongated pyloric canal can usually be easily delineated (normal value for muscle thickness up to 3–4 mm, length of pylorus canal up to 15–19 mm) (▶ **Fig. 4b**) [17].



▶ **Fig. 4** **a** 8-year-old boy – ultrasonography of the transverse mid-abdomen. Significant thickening of the intestinal wall in multifocal Burkitt lymphoma. **b** 2-month-old infant. Transverse ultrasound of the upper abdomen. Projectile vomiting. Elongated pyloric canal with increased diameter and thickened muscular wall. Increase in wall thickness from the prepyloric antrum to the pyloric canal **c**, **d** 5-year-old boy, abdominal cramps and therapy-resistant constipation. On the following day clinical deterioration and bilious vomiting. **c** Intraoperative site **d** X-ray ileus. Evidence of 5 small bowel perforations caused by 7 ultra-magnets and an attached nail.

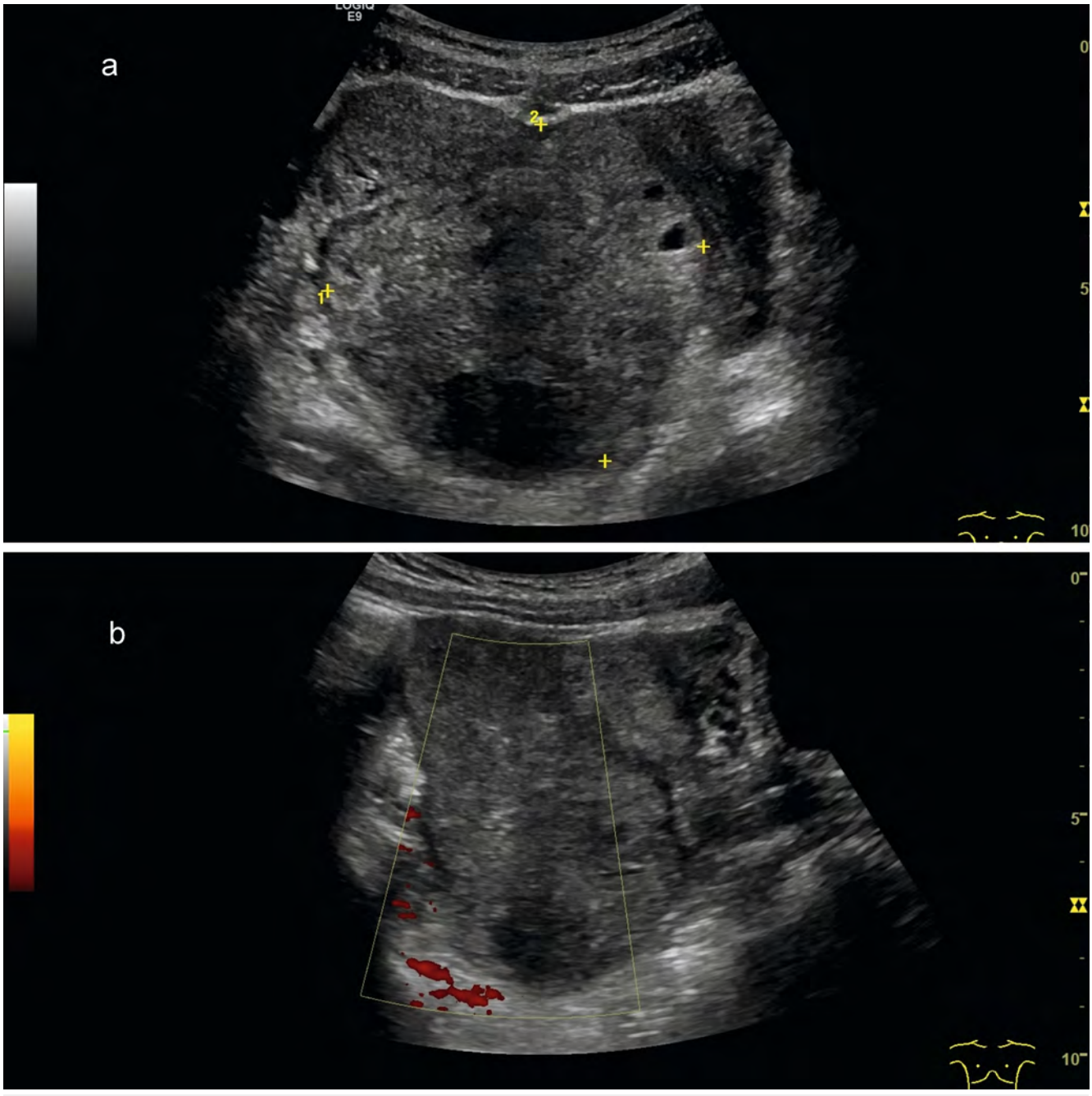
The passage of fluid through the pyloric canal excludes a pyloric stenosis. Complementary examinations, specifically a gastrointestinal transit examination are only indicated in the case of inconclusive findings or an atypical presentation [18].

Meckel's diverticulum (incomplete occlusion of Ductus omphaloentericus, occurs in approximately 2 % of the population) is usually asymptomatic. There is low sensitivity of imaging for visualization of a non-inflammatory Meckel's diverticulum. Symptoms of Meckel's diverticulum can occur at any age. However, 25–50 % of symptomatic Meckel's diverticulum cases have been described in children under 10 years of age, most commonly involving an obstruction. As mentioned above, an inverted Meckel's diverticulum can be a pathological sign of an intussusception. In the case of inflammation, differentiation from appendicitis can be difficult [19, 20]. **The ingestion of foreign bodies** is most commonly observed in children between 6 months and 3 years of age. This is generally asymptomatic [21]; however, when batteries or magnets are ingested, caution is warranted. Ingestion of a button



▶ **Fig. 5** **a** 11-year-old child. Acute symptoms and abnormal laboratory parameters, with an appendix that cannot be demonstrated sonographically. MRI abdomen STIR cor 4 mm. Round low-signal appendicolith in the right lower quadrant with surrounding free fluid and tissue edema. **b** 15-year-old boy. Transverse sonography of the right lower abdomen. Elevated temperature for 3 days. Last vomited 2 days ago. Inflamed, thickened appendix pictured twice with marked hyperechoic surrounding reaction. Laparoscopic findings: ulcerophlegmonous appendicitis. **c** 8-year-old boy. Transverse sonography of the right lower abdomen. Abdominal pain and vomiting since the previous day. Hyperechoic structure with acoustic shadows due to appendicolith. Intraoperative findings: ulcerphlegmonous appendix. **d** 12-year-old boy. Transverse sonography of the right lower abdomen. Nausea and vomiting. Subfebrile. Cross-section through the inflamed appendix in the right lower abdomen (ventrally inconspicuous terminal ileum). Intraoperative findings: perforated appendicitis.

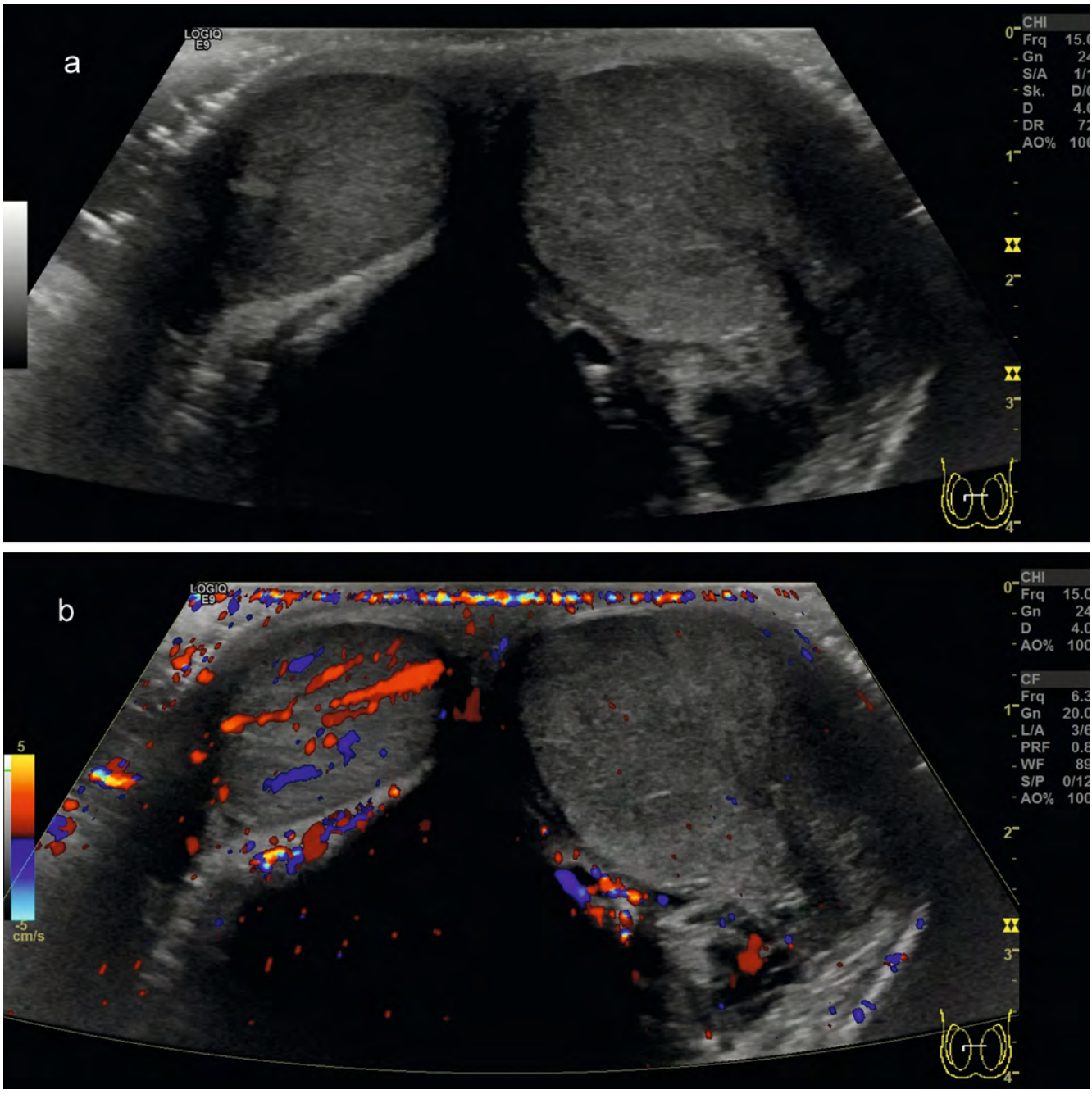
battery is an emergency, as necrosis occurs very quickly, especially in the esophagus. Magnetic foreign bodies may be problematic especially in the case of the ingestion of multiple magnets, which may induce peristaltic disorders and subsequently intestinal wall necrosis if the magnets are positioned in different regions of the tract, e. g., the small intestine (▶ **Fig. 4c, d**). Generally, other foreign bodies that have passed through the stomach do not cause problems. Exceptions have been described [21]. X-ray dense foreign bodies such as magnetic and button batteries are easily detected with X-ray projection techniques; To reduce the radiation dose, we use a low-dose technique on the fluoroscopy device (documentation using the “last image hold” function).



▶ **Fig. 6 a, b** 14-year-old girl **a** B-mode **b** Color Doppler, abdominal pain in right lower abdomen for 4 days. Right ovary significantly enlarged, multiple cysts in the periphery, lack of perfusion. Intraoperative findings: 360° ovarian torsion.

Bowel duplication (or cyst duplication) is a less common incidental finding on abdominal ultrasound. It typically presents as a cyst formation with a multilayered wall adjacent to a bowel structure. Intra-abdominal duplications are found in 53 % of cases in the ileum [22]. Symptomatic duplications can present very differently (e. g., as a palpable mass, intussusception, obstruction).

Acute abdominal pain symptomatology is not uncommon in basal pneumonias! We see this repeatedly in the context of primary diagnostics, usually in connection with the initial sonographic examination. Therefore, when taking X-ray abdominal overview images, it is important to carefully inspect the basal lung sections included in the image. As a rule, imaging is not required for the diagnosis of uncomplicated gastroenteritis.



▶ **Fig. 7 a, b** 15-year-old boy **a** B-mode **b** Color Doppler sonography 4 hours after the onset of symptoms on the left side of the scrotum, significantly enlarged left testicle, extensive loss of perfusion in comparison to the right testicle. Intraoperative findings: 720° torsion.

School children and adolescents (6–18 years)

The most common pathologies causing an acute abdomen in school children and adolescents include **appendicitis** and, in girls, **ovarian torsion**.

The most important differential diagnoses include:

- Gastroenteritis
- Yersiniosis
- Testicular torsion
- Pyelonephritis
- Chronic inflammatory bowel disease

The frequency peak for appendicitis is 9–14 years of age. In younger children, the clinical picture can appear completely normal [23, 24]. The clinical picture of appendicitis is described as right-sided abdominal pain, which may begin in the epigastric or periumbilical region [24]. As the disease progresses, the pain migrates to the right abdomen. Concomitant findings include muscular tension, one-time vomiting, fever, leukocytosis, and CRP elevation, although not all of the above symptoms may be present. Ultrasound is leading the way in diagnostic imaging. In experienced hands, a sensitivity between 74 % and 100 %, and specificity of 88 % to 99 %, has been reported [25]. An abdominal overview

image is only necessary if there are indications of complications (e. g., obstruction, perforation). If the appendix cannot be detected sonographically and in the absence of other inflammatory changes, acute appendicitis is less likely, and a follow-up the next day is the recommended course of action [26]. If the clinical and sonographic findings are unclear, supplementary cross-sectional imaging may be necessary. High sensitivity and specificity have been reported for computed tomography [25]. Recent data do not show any disadvantages in terms of using MRI to address this question (▶ **Fig. 5a**) [27]. This is why the current German guidelines only recommend CT for children and adolescents in exceptional cases to minimize exposure to radiation [28].

Ultrasound allows the appendix to be visualized as a blind-ended tubular structure localized to the right abdomen. It identifies the typical wall layers of the intestinal wall, but without discernible peristalsis [29]. Indicative of appendicitis is an increase in transverse diameter > 6 mm, abolition of wall stratification, hyperechogenic environmental reaction, hyperemia, and locoregional lymph node enlargement. Free fluid may occur locally or in the pouch of Douglas. In addition, the clear indication of pain on deep sonopalpation in the right lower abdomen is suggestive of an inflammatory altered appendix vermiformis. In most cases, an appendicolith can be detected [30]. Depending on the stage of inflammation, not all symptoms are present here (▶ **Fig. 5b–d**). It ranges from tip appendicitis to perityphlitic abscess with four-quadrant peritonitis. If **appendicitis is already perforated**, the appendiceal wall is no longer delineable, at least in most cases. Free fluid can often be detected. In some cases, the appendix itself is no longer detectable. Instead, there is a mostly anechoic mass located in the right abdomen and surrounded by hyperechoic tissue. Centrally, no perfusion can be detected in the formation; hyperperfusion is found in the surrounding area. Free perforation into the peritoneal cavity often reveals interenteric echogenic fluid as evidence of peritonitis [24]. Another important cause of acute abdomen in girls (with a peak during puberty) is ovarian torsion. This involves a torsion of the ovarian vessels and/or the tube with subsequent interruption of arterial blood supply and a decrease in venous outflow. Patients usually report a sudden onset of abdominal pain on the right or left side. Sometimes nausea or vomiting are also reported [29, 30]. Ultrasound usually gives a clear picture [31, 32] of a unilateral organ enlargement (at least up to twice the normal organ size) and a displacement of the affected ovary to the midline (▶ **Fig. 6**). Typically, follicles may be lined up at the edges. The Doppler sonographic evidence of perfusion does not exclude torsion (dual vascular supply: ovarian and uterine artery) [24]. In rare cases, further diagnostic confirmation by MRI is required; In particular, if an ovarian tumor is suspected to cause the torsion or if it is sonographically difficult to differentiate from an ovarian cyst hemorrhage. Large ovarian cysts can also occasionally cause symptoms, hemorrhage, or rupture. In this case, there is usually plenty of fluid in the pouch of Douglas [32]. In boys, testicular torsion can lead to sudden onset of lower abdominal pain and also vomiting. Testicular torsion is the rotation of the testicle in the longitudinal axis of the Funiculus spermaticus. The age peak is between 12 and 18 years [24]. Here, too, the realm of diagnostic imaging primarily centers on sonography, followed by Doppler sonography. The affected testis may appear

OP-VIDEO

▶ **Video 3**

enlarged and more anechoic compared to the other side. At the same time, a lateral comparison may also no longer detect central vessels by Doppler sonography, and a scrotal edema may occur (▶ **Fig. 7**) [24]. Torsion of the spermatic cord can be documented by imaging (▶ **Video 3**). Increasingly heterogeneous testicular tissue suggests a necrotic zone. Both ovarian torsion and testicular torsion are a real emergency, as the time to detorsion is crucial for the subsequent functional capacity of the affected organ. Therefore, in the case of a strong clinical suspicion of torsion, treatment should not be delayed by performing diagnostic imaging.

In the testis, nearly 100 % functional capacity can be preserved after a maximum of 6 hours of ischemia. After approx. 12 hours of ischemia, only approximately 20–70 % of testicular function is retained [23]. The differential diagnoses that are well-established in adult medicine will not be discussed further here.

Summary

The causes of acute abdomen during childhood and adolescence differ greatly from those in adulthood. Ultrasound is the primary diagnostic imaging tool for diagnosing an acute abdomen. Sonographic diagnosis is often sufficient to establish the diagnosis; in the case of intussusception, it is also helpful for treatment/therapy. Additionally, conventional X-ray and fluoroscopy examinations are necessary, depending on the issue. Cross-sectional imaging on large equipment (preferably MRI for reasons of radiation hygiene) is indicated only in selected cases – usually in larger children and adolescents. Close interdisciplinary cooperation between the different specialties involved is essential for good patient care.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Gayoung C, Bo-Kyung J, Yu JK. Gastrointestinal Emergency in Neonates and Infants: A Pictorial Essay Korean. J Radiol 2022; 23 (1): 124–138

[2] Michel A et al. Hypothyreose bei Neugeborenen nach intestinaler Verabreichung von jodhaltigem Kontrastmittel- Fallberichte und Literaturübersicht. Fortschr Röntgenstr 2021; 193 (Suppl. 2): S90A

[3] Deeg KH, Sonographische U. Dopplersonographische Diagnose der nekrotisierenden Enterokolitis bei Früh- und Neugeborenen. Ultraschall in der Medizin 2019; 40: 292–318

[4] Genzel-Boroviczény O, Jenke A, Mihatsch W et al. Nekrotisierende Enterokolitis (NEK). Leitlinie der Gesellschaft für Neonatologie und Pädiatrische Intensivmedizin, der Deutschen Gesellschaft für Kinder- und Jugendmedizin, der Gesellschaft für Pädiatrische Gastroenterologie und Ernährung und der Deutschen Gesellschaft für Kinderchirurgie. https://register.awmf.org/de/leitlinien/detail/024-009

[5] Epelman M et al. Necrotizing Enterocolitis: Review of State of the Art Imaging Findings with Pathologic Correlation. Radiographics 2007; 27 (2): 285–305. doi:10.1148/rg.272055098

[6] Roopali S et al. How to use abdominal X rays in preterm Infants suspected ofdeveloping necrotising enterocolitis. Arch Dis Child Educ Pract Ed 2020; 105 (1): 50–57. doi:10.1136/archdischild-2018-315252

[7] Okuyama H et al. A comparison of the clinical presentation and outcome of focal intestinal perforation and necrotizing enterocolitis in very-low-birth-weight neonates. Pediatr Surg int 2002; 18: 704–706

[8] Anjali V et al. Neonatal Intestinal Obstruction: A 15 Year Experience in a Tertiary Care Hospital. J Clin Diadn Res 2016; 10 (2): SC10-3. doi:10.7860/JCDR/2016/17204.7268

[9] Gorter RR, Karimi A, Sleebom C et al. Clinical and genetic characteristics of meconium ileus in newborns with and without cystic fibrosis. J Pediatr Gastroenterol Nutr 2010; 50 (5): 569

[10] Mandeville K et al. Intussusception: clinical presentations and imaging characteristics. Pediatr Emerg Care 2012; 28 (9): 842–844

[11] Ko HS et al. Current radiological management of intussusception in children. Eur Radiol 2007; 17 (9): 2411

[12] Plut D et al. Practical Imaging Strategies for Intussusception in Children. Am J Roentgenol 2020; 215 (6): 1449–1463. doi:10.2214/Am J Roentgenol.19.22445

[13] Edwards EA, Pigg N, Courtier J et al. Intussusception: past, present and future. Pediatr Radiol 2017; 47: 1101–1108. doi:10.1007/s00247-017-3878-x

[14] Shen G, Liu H, Guan Z et al. Clinical features and factors leading to early recurrence of intussusception after saline reduction. J Pak Med Assoc 2020; 70 (10): 1727–1730

[15] Guo WL, Hu ZC, Tan YL et al. Risk factors for recurrent intussusception in children: a retrospective cohort study. BMJ Open 2017; 7 (11): e018604. doi:10.1136/bmjopen-2017-018604

[16] Chang WL, Yang YH, Lin YT et al. Gastrointestinal manifestations in Henoch-Schönlein purpura: a review of 261 patients. Acta Paediatr 2004; 93 (11): 1427

[17] Hernanz-Schulman M. Pyloric stenosis: role of imaging. Pediatr Radiol 2009; 39 (Suppl. 2): S134–S139

[18] Sivitz AB, Tejani C, Cohen SG. Evaluation of hypertrophic pyloric stenosis by pediatric emergency physician sonography. Acad Emerg Med 2013; 20 (7): 646–651

[19] Zani A et al. Incidentally detected Meckel diverticulum: to resect or not to resect? Ann Surg 2008; 247 (2): 276

[20] Chen Q. Multifaceted behavior of Meckel's diverticulum in children. J Pediatr Surg 2018; 53 (4): 676

[21] Uyemura MC. Foreign body ingestion in children. Am Fam Physician 2005; 72 (2): 287

[22] Sharma S, Yadav AK, Mandal AK et al. Enteric Duplication Cysts in Children: A Clinicopathological Dilemma. J Clin Diagn Res 2015; 9 (8): EC08-11. doi:10.7860/JCDR/2015/12929.6381

[23] Wunsch R, Wunsch C. Bildgebung beim akuten Abdomen im Kindes- und Jugendalter. Radiologe 2014; 54: 923–936, Springer-Verlag Berlin Heidelberg 2014

[24] Krüger PC, Menzel HJ. Radiologische Abklärung des akuten Abdomens beim Kind. Radiologe 2019; 59: 146–153

[25] Doria AS, Moineddin R, Kellenberger CJ. US or CT for Diagnosis of Appendicitis in Children and Adults? A Meta-Analysis. Radiology 2006; 241 (1): 83

[26] Telesmanich ME, Orth RC, Zhang W et al. Searching for certainty: findings predictive of appendicitis in equivocal ultrasound exams. Pediatr Radiol 2016; 46 (11): 1539

[27] Duke E, Kalb B, Arif-Tiwari H. A Systematic Review and Meta-Analysis of Diagnostic Performance of MRI for Evaluation of Acute Appendicitis. Am J Roentgenol 2016; 206 (3): 508–517

[28] https://register.awmf.org/assets/guidelines/064-016l_S1_Bauchschmerz_Kinder_2020-07.pdf

[29] Deeg KH, Hofmann V, Hoyer PFR. Ultraschalldiagnostik in Pädiatrie und Kinderheilkunde. 4. Auflage Stuttgart: Thieme; 2014

[30] Hörmann M, Scharitzer M, Puig S. Das akute Abdomen beim Kind. Radiologe 2002; 42: 162–170, Springer Verlag

[31] Moro F, Bolomini G, Sibal M et al. Imaging in gynecological disease (20): clinical and ultrasound characteristics of adnexal torsion. Ultrasound Obstet Gynecol 2020; 56 (6): 934

[32] Chang HC, Bhatt S, Dogra VS. Pearls and pitfalls in diagnosis of ovarian torsion. Radiographics 2008; 28 (5): 1355–1368. doi:10.1148/rg.285075130