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REVIEW

The pediatric stomach — masses and mass-like pathology

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Abstract
Diagnostic imaging of pediatric gastric masses often provides a challenge for the practicing radiologist. Radiologists should be aware of this relatively unusual pathology, particularly in cross-sectional imaging findings. We will review pediatric gastric masses and mass-like lesions, focusing on neoplastic and inflammatory etiologies.

Keywords Children · Computed tomography · Fluoroscopy · Gastrointestinal · Imaging · Inflammatory disease · Mass · Neoplasm · Stomach

Introduction

In this article, we discuss the imaging approach to the pediatric stomach, with a primary focus on masses and mass-like pathology, which are relatively rare in infants and children [1]. Excluding hypertrophic pyloric stenosis, there is a relative paucity of recent medical literature addressing diagnostic imaging of the pediatric stomach, particularly relating to cross-sectional imaging. Our discussion will include neoplasms, gastric bezoars and inflammatory pathology. Hypertrophic pyloric stenosis, which has been well characterized [2, 3], will not be detailed.

Anatomy and imaging technique

The stomach is divided anatomically into the cardia, fundus, body, antrum and pylorus; it originates proximally at the gastroesophageal junction and terminates distally at the pylorus. The variable shape and imaging appearance of the stomach depend on patient age, size and body habitus. Infants tend to have a high transversely oriented stomach. The stomach in older children and adults is more typically J-shaped.

Although primary gastric pathology is relatively rare, radiologists are commonly asked to evaluate the stomach and upper gastrointestinal tract in children with vomiting or upper abdominal pain. Imaging can be accomplished using a variety of modalities; each carries inherent advantages and limitations.

Radiography

Standard abdominal radiography provides an initial evaluation. Gastric contours are delineated by intraluminal gas and peritoneal fat. An abnormally displaced, air-filled stomach may indicate a left upper quadrant mass (Fig. 1) [4]. A gas-filled stomach helps confirm situs, and a dilated gas-filled stomach may represent gastric outlet obstruction from a mass or mass-like lesion. Notably, air that is swallowed by a crying infant may mimic gastric outlet obstruction or gastroparesis. This, of course, can be excluded by repeating radiographs after the child eructates, or, if necessary, by applying manual suction with a nasoenteric catheter. Radiography alone has limited utility for evaluating gastric masses or mass-like lesions.

Fluoroscopy

Although gastroscopy is the reference standard for intraluminal evaluation, fluoroscopy remains important for evaluating suspected gastric disease in children, including masses and mass-like conditions. The orientation of the stomach, its relation to adjacent anatomy, real-time peristalsis, and the presence of

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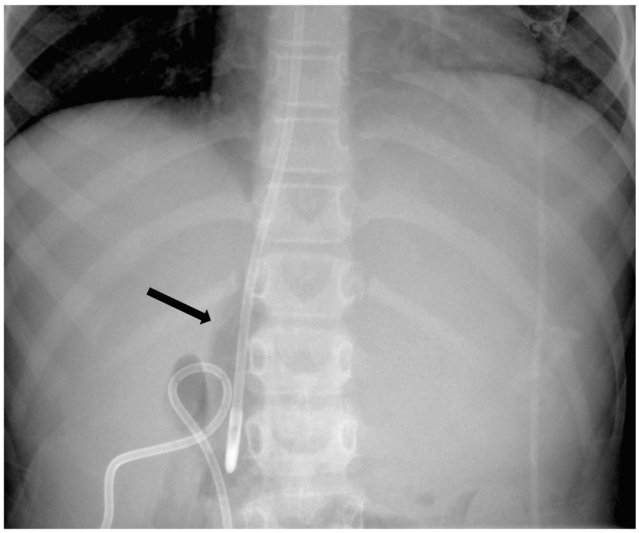

Fig. 1 Displaced stomach in a 3-year-old boy with known left-side Wilms tumor presenting for a supine abdominal radiograph. A transesophageal catheter is placed into the stomach, and the gastric bubble (*arrow*) is displaced to the right of midline by the known space occupying mass

intraluminal or extraluminal masses can all be evaluated fluoroscopically with enteric contrast media. In infants and children, a single-contrast technique is typically used [5]. Double-contrast technique with mucosal relief is unlikely to yield additional diagnostic information in most clinical situations, and it is rarely performed in children [5]. However, intraluminal gastric masses, which typically appear as a filling defect on fluoroscopy, may be better evaluated by the double-contrast technique, particularly when the lesion is small. Nonetheless, barium sulfate suspension is the contrast medium of choice when evaluating the stomach. Water-soluble iodinated contrast media is preferable if perforation is suspected. Most fluoroscopy units permit radiation dose reduction while maintaining diagnostic quality [6].

Ultrasonography

Ultrasonography (US) is commonly utilized when hypertrophic pyloric stenosis is suspected in infants. Sonographic evaluation of the stomach in older children can be hindered by sound-attenuating phenomena such as superficial fat and intraluminal gas. The latter can be mitigated by having patients drink fluid immediately before examination. This may help provide an acoustic window, particularly when a gastric mass is suspected. Administering fluid during the examination can also be performed as a problem-solving tool, both to assess peristalsis through the pylorus, and to increase conspicuity of findings during real-time scanning. Mild transducer compression can be useful to assess gastric wall thickness, which can be measured from the outer surface of the stomach wall to the air-mucosal interface. Some variability exists depending on alimentary contraction. Sonographic gastric wall thickness of 3–6 mm is considered normal in children, with the antrum measuring up to 7 mm [7, 8]. Because of the excellent spatial resolution that US provides, the five discrete layers within the gastric wall may be visible. The echogenic inner mucosal and outer serosal margin will envelop the hypoechoic muscularis [9].

Computed tomography

Abdominal computed tomography (CT) is often requested to evaluate a wide variety of clinical indications, including trauma, intractable abdominal pain, suspected acute appendicitis, suspected or known inflammatory bowel disease, or suspected or known neoplasia [10]. Modern multidetector scanners provide excellent spatial resolution, and rapid imaging capabilities can minimize sedation use in many patients [11]. Nevertheless, evaluating the stomach with CT can be challenging. Its use should be judicious and weighed against the inherent risks of ionizing radiation. Iodine-based enteric contrast media administered immediately before imaging can substantially improve opacification of the gastric lumen and intraluminal gastric masses, but it generally provides limited evaluation of gastric mucosa and submucosa. Intravenous iodine-based contrast media substantially improves visualization of gastric masses. Neutral enteric contrast media, which is often utilized in the context of suspected inflammatory bowel disease, can also be useful for evaluating gastric masses and mass-like lesions. Gastric wall thickening is often artificially exaggerated by luminal underdistention (pseudothickening). Normal values have proven difficult to verify. Some suggest that a normal gastric body and gastric antrum can measure up to 5 mm and 12 mm, respectively [12, 13], but these measurements have not been validated in children.

Magnetic resonance imaging

Magnetic resonance imaging (MRI) provides exceptional contrast resolution and is increasingly preferred for pediatric abdominal imaging. Abnormal T2 signal prolongation within parenchymal tissue may suggest pathology. Diffusion-weighted imaging may be valuable for differentiating normal from abnormal gastric tissue, particularly neoplasia. Although free of ionizing radiation, abdominal MRI holds certain disadvantages for children. Infants and young children often require sedation, which is increasingly recognized as a factor to be considered cautiously when choosing cross-sectional modalities [14]. As with CT, the underdistended gastric wall may falsely appear thickened (Fig. 2) on MRI. Sedated infants, young children and developmentally delayed patients often cannot tolerate breath-holding sequences that reduce misregistration artifact [15]. This may necessitate using respiratory-triggered sequences or radial non-Cartesian sequence techniques. At many institutions, sedated patients cannot receive enteric contrast immediately before imaging, which may

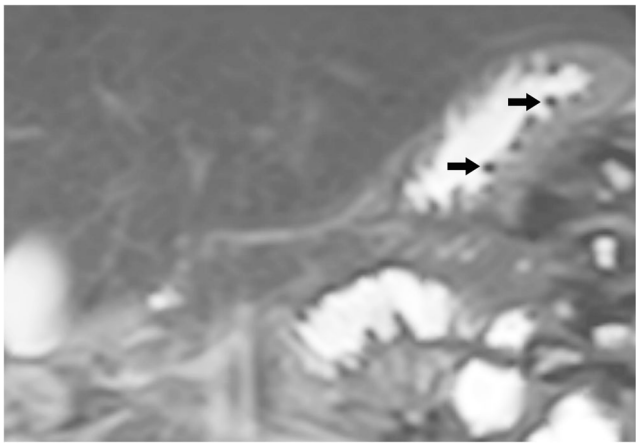

Fig. 2 Normal stomach in an 18-year-old man with abdominal pain and persistent vomiting. Non-contrast T2-weighted MR imaging of the abdomen in the coronal plane was performed; the rugal folds appear prominent (*arrows*) and gastritis was offered as a differential consideration. Subsequent optical endoscopy revealed a normal stomach. The appearance is on account of an underdistended lumen

preclude optimal gastric distension. As with CT, neutral enteric contrast media is commonly administered for magnetic resonance enterography when inflammatory bowel disease is suspected.

Positron emission tomography

Positron emission tomography (PET) is useful for imaging metabolically active malignancies and infections that incorporate fluorodeoxyglucose (FDG), a competitive glucose analog. PET is typically fused with concurrently acquired CT or MRI, which permits more precise anatomical localization and tissue characterization. This technique identifies gastric pathology when abnormal FDG avidity resides within the stomach wall. A disadvantage of PET imaging is that normal physiological FDG excretion occurs through the enteric tract. The lumen, therefore, can falsely appear to be metabolically active. True pathology may be masked when physiological excretion occurs immediately adjacent to an FDG avid lesion.

Primary masses/tumors

Primary gastric malignancies are rare in children. Gastric polyps may be entirely benign or serve as malignant precursors. Primary neoplasms include lymphoma, gastrointestinal stromal tumor, small round blue cell tumors and teratomas.

Polyp

Patients with familial adenomatous polyposis (such as Gardner syndrome) are subject to developing adenomatous gastric polyps, which carry a risk of malignant transformation. Juvenile polyposis patients often present with hyperplastic polyps [16], which are generally benign. Patients with Peutz-Jegher syndrome may develop hamartomatous polyps, which have malignant potential [17]. Gastric polyps in children are rare outside of specific syndromes. A meta-analysis from Johns Hopkins Children's Center identified 35 patients over a 17-year period and 5,766 endoscopies [18].

Imaging findings of gastric polyps are not well described except in adults, for whom double-contrast fluoroscopic technique is routinely used [19]. With single-contrast fluoroscopy, one would expect gastric polyps to appear as circumscribed soft-tissue filling defects (Fig. 3). Mucosal soft-tissue masses remain difficult to diagnose with imaging in children not only because the single-contrast technique is suboptimal for their evaluation, but also because of their low baseline prevalence. The mainstay for detecting and diagnosing gastric polyps is therefore optical endoscopy.

Lymphoma

Lymphoma is a relatively common neoplasm in children, but primary gastric lymphoma is rare. To our knowledge, the few existing case reports are limited to examples of non-Hodgkin lymphoma — either Burkitt type, or MALT (mucosa-associated lymphoid tissue) lymphoma in the setting of chronic Helicobacter pylori infection. Imaging findings include diffuse gastric wall thickening and FDG avidity within gastric tissue on PET studies (Fig. 4), as opposed to physiological endoluminal activity [20–22]. Mucosal ulceration may also

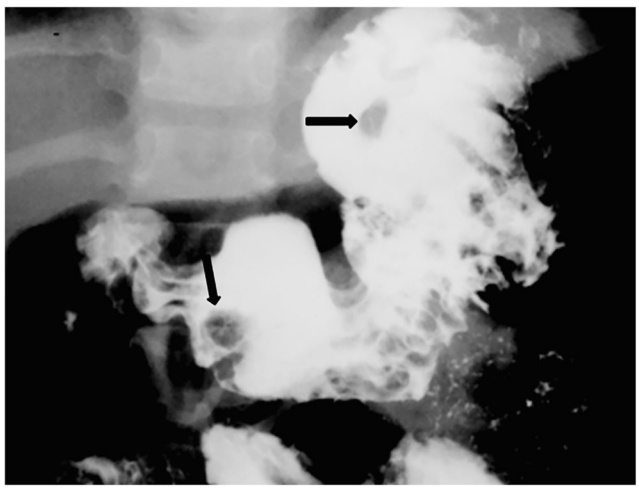

Fig. 3 Gastric polyps in an 11-year-old boy who presented with abdominal pain. Filling defects are identified (*arrows*) in the gastric fundus and body on a single-contrast fluoroscopic study in the frontal projection [12]. These were endoscopically and histologically confirmed as hamartomatous polyps in the setting of Peutz-Jeghers syndrome. The patient had polyps throughout the enteric tract and a small bowel intussusception

be demonstrated. On CT imaging, lymphomatous tissue will typically homogeneously enhance, although areas of necrosis are possible [23]. The preservation of perigastric fat planes abutting diseased gastric tissue is a characteristic feature of lymphoma [24, 25]. Gastric lymphoma may also present as a focal mass, although this has only been described in adults. Focal gastric lymphoma may manifest sonographically as a hypoechoic mass that can be located anywhere in the stomach [26]. Such findings have been described using endoscopic US [27], which is less commonly utilized in pediatrics. All modalities may detect associated findings such as splenomegaly and lymphadenopathy.

Gastrointestinal stromal tumor

Gastrointestinal stromal tumors (GISTs) derive from the interstitial cells of Cajal in the alimentary tract muscular wall. GIST is considered malignant, although the prognosis is favorable if the mitotic index is low, tumor size is <5 cm and lymphadenopathy is absent [28]. Malignant GISTs are rare in children. GISTs originate predominantly in the stomach and may present with upper intestinal bleeding due to endoluminal cavitation (Fig. 5) [29]. Unlike in adults, GISTs in children are rarely found distal to the stomach [30]. GISTs can be associated with the Carney triad (GIST, pulmonary chondroma and extra-adrenal paraganglioma) and neurofibromatosis type 1. Large GISTs (>5 cm) are usually exophytic with heterogeneous parenchyma and enhancement secondary to internal necrosis and hemorrhage. These findings may be identified on US (heterogeneous echotexture with areas showing both the presence and absence of Doppler flow), CT (heterogeneous attenuation with areas of hypoattenuating necrosis) or MRI (heterogeneous intensity on T2-weighted imaging, with areas of higher T2 signal indicative of necrosis and showing relative hypoenhancement on post gadolinium imaging). Larger tumors with high mitotic rate may also present with metastases, or extend to the liver, peritoneum and abdominal lymph nodes [28]. Smaller tumors are typically submucosal, more homogeneous and diffusely hypervascular. Although smaller tumors are more challenging to identify than larger lesions, they can be identified on the same three imaging modalities; power Doppler US may be useful in US to demonstrate increased vascularity relative to adjacent normal stomach parenchyma. Restricted diffusivity on MRI correlates to high-risk disease in adults, although it has not been investigated in children [31].

Teratoma

Teratomas are germ cell tumors. Gastric teratomas are rare. Less than 1% originate in the stomach, and they have been described only in case reports and small case series. They almost always present within the first 2 years of life,

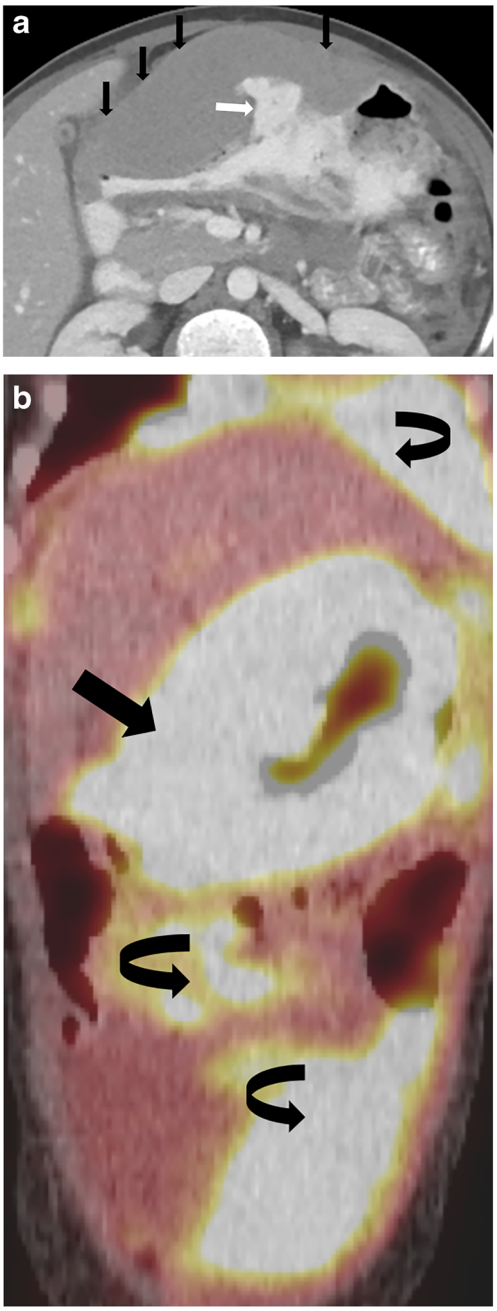

Fig. 4 Burkitt lymphoma in an 11-year-old girl who presented to the emergency department with fatigue, vague mid-abdominal discomfort and microcytic anemia. **a** CT imaging in the axial plane with intravenous and enteric contrast. The ventral wall of the stomach is diffusely infiltrated with abnormal soft tissue (*black arrows*), and there is a large endoluminal ulcer, demonstrated as mucosal cratering with enteric contrast (*white arrow*). Lymphadenopathy posterior to the stomach is present. **b** Fused PET/CT imaging in the coronal plane demonstrates that the entire stomach wall (*straight black arrow*) is intensely fluorodeoxyglucose (FDG) avid, as depicted by fluorescent white color tone. *Curved black arrows* point to physiological uptake of radiopharmaceutical in the normal thymus, as well as physiological excretion in the small bowel lumen

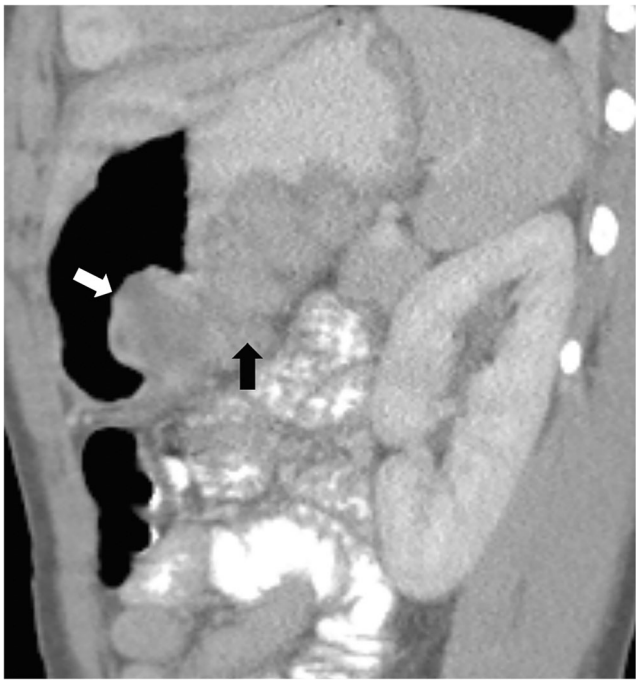

Fig. 5 Gastrointestinal stromal tumor in an 11-year-old boy who presented with anemia and melena; endoscopy showed a hemorrhagic submucosal mass. Contrast-enhanced CT in the sagittal plane shows a multilobulated soft-tissue intramural mass (*black arrow*) extending to the mucosal surface (*white arrow*). He was treated with partial gastrectomy in 2014, but developed hepatic metastases 6 months after surgery

particularly when large, and they have been found predominantly in boys. On rare occasions, gastric teratomas have been diagnosed prenatally [32]. Large gastric teratomas may cause respiratory compromise and emesis. Endoluminal extension may cause substantial gastric bleeding [33]. These tumors contain variable amounts of calcification and fat (Fig. 6). They tend to occur along the lesser curvature, antrum or posterior fundal wall [34]. Despite these characteristic imaging findings, definitive differentiation between immature and mature teratomas requires histopathological correlation.

Gastric adenocarcinoma

Although adenocarcinoma is a common malignancy of the stomach in adults, it is exceedingly uncommon in children. Indeed, in a 10-year review of the National Cancer Database, 0.1% of all cases of gastric adenocarcinoma were in patients <21 years [35]. Nearly all of the 129 instances of this malignancy were in children older than 10 years. The disease at presentation is more advanced in children than in adults, but the survival rates are comparable [35]. Imaging features in the pediatric population may include mucosal thickening, omental caking and ascites [36].

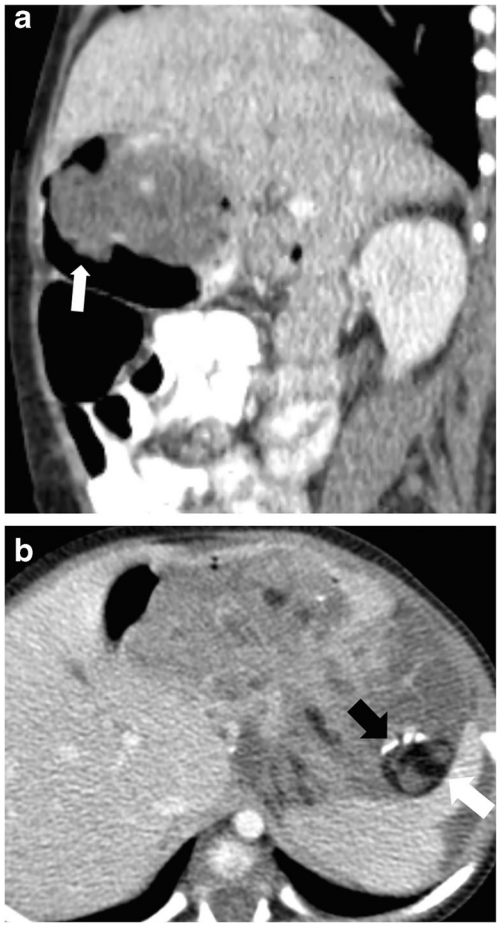

Fig. 6 Gastric teratoma in a 5-month-old boy who presented to our institution with anemia and intermittent melena, initially thought to be due to milk allergy. CT performed with intravenous and enteric contrast demonstrated a massive tumor arising from the stomach. **a** In the sagittal plane, pedunculated soft-tissue components protrude into the gastric lumen (*white arrow*). **b** In the axial plane, multiple foci of hypoattenuating fat (*white arrow*) and calcifications (*black arrow*) are identified within the tumor. The patient went on to total resection of a mature teratoma

Secondary neoplastic involvement of the stomach

Desmoplastic small round blue cell tumor

Desmoplastic small round blue cell tumor is a rare, malignant neoplasm of mesenchymal origin. Prognosis for desmoplastic small round blue cell tumor is poor, with a 5-year survival rate of less than 15% [37]. Desmoplastic small round blue cell tumors occur most commonly in young adults but can also affect older children. They have a predilection for the peritoneal cavity, and patients may present with a dominant abdominal or pelvic mass, with secondarily disseminated disease. In such instances, there may be secondary gastric involvement

[38]. Patients often present with abdominal pain, weight loss, or symptoms related to mass effect on adjacent intra-abdominal structures [39]. While imaging findings specific to the stomach have not been previously reported, in our experience the manifestations tend to reflect the aggressive nature of the disease. The tumor is often partially necrotic; US, CT and MRI will demonstrate heterogeneous parenchyma with irregular borders and preserved vascularity in non-necrotic portions. Local peritoneal metastases are common at presentation (Fig. 7).

Inflammatory myofibroblastic tumor

A rare and technically benign neoplasm, hence its second moniker, inflammatory pseudotumor, inflammatory myofibroblastic tumor predominantly affects a younger patient population, including children [40, 41]. It is an aggressive collection of inflammatory and spindle cells, and although it is not histologically malignant, inflammatory myofibroblastic tumor is prone to invasion, necrosis and recurrence [40, 42]. Inflammatory myofibroblastic tumor most commonly occurs in the lungs and orbits, but can manifest anywhere in the body [43, 44]. When involving the stomach, CT or US may depict diffuse infiltration of the distal portions of the stomach with either hypoattenuating or hypoechoic features (Fig. 8) [44]. Fluoroscopic interrogation may depict ulceration.

Mass-like lesions

Gastric ulcer disease

Although peptic ulcer disease is rare in children, perforation is a surgical emergency. A single institution's retrospective analysis reported that 20% of pediatric perforated ulcers occurred in the stomach [45], most in the duodenum. Children, like adults, will generally present with peritoneal signs when perforation occurs. Patients with suspected perforated gastric ulcers should undergo urgent CT evaluation, although unexpected free intraperitoneal air on a radiograph generally necessitates surgical evaluation. Imaging may demonstrate mucosal cratering with surrounding inflammation and gas locules (Fig. 9), or frank pneumoperitoneum, and the diagnosis should be considered when pneumoperitoneum occurs in the absence of trauma. This entity can present as a mass-like lesion because of associated inflammation. The diagnosis is ultimately confirmed by the endoscopist or surgeon.

Bezoar

Bezoars are formed by the ingestion of indigestible material, which coalesces to form an intraluminal mass in the alimentary tract — the stomach is the most common location. The entity is subdivided into phytobezoars (plant material), pharmacobezoars (medications), lactobezoars (milk protein) and trichobezoars (hair) [46]. The latter two are more common in children. Lactobezoar formation is considered multifactorial. It is often seen in premature neonates who are administered high-calorie

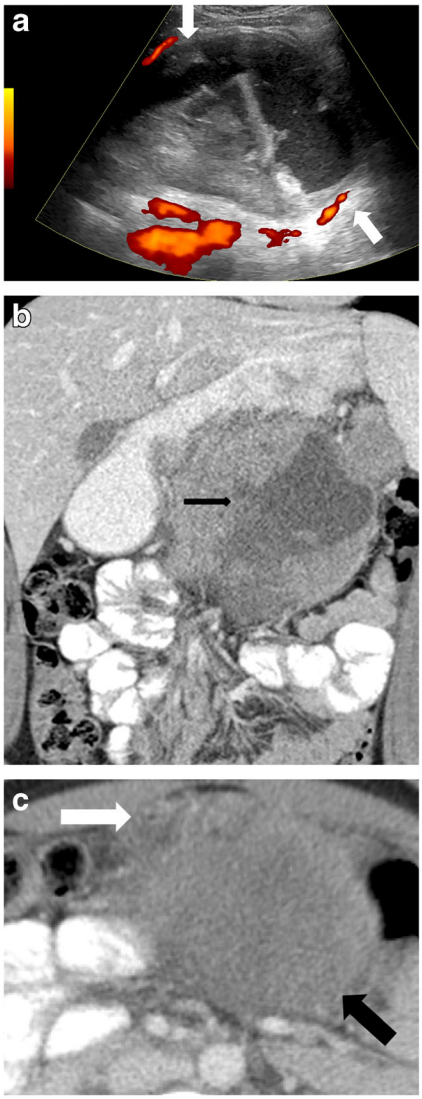

Fig. 7 Desmoplastic small round blue cell tumor in a 15-year-old girl who presented with persistent constipation and sensation of fullness. **a** Transabdominal sonographic interrogation of the left upper quadrant with power Doppler demonstrated a 13.8-cm heterogeneous mixed cystic/solid intragastric mass with both vascularized and avascular components. *White arrows* demarcate the borders of the mass. **b**, **c** Corresponding CT with enteric and intravenous contrast in coronal (**b**) and axial (**c**) reconstruction demonstrates a large necrotic mass arising from the greater curvature of the stomach (*black arrows*), with associated omental nodularity (*white arrow*, **c**). The patient was diagnosed with desmoplastic small round blue cell tumor of the stomach with disseminated disease in the peritoneum, secondarily involving the stomach. The patient ultimately required partial gastrectomy, omentectomy, splenectomy, distal pancreatectomy and hyperthermic intraperitoneal chemotherapy

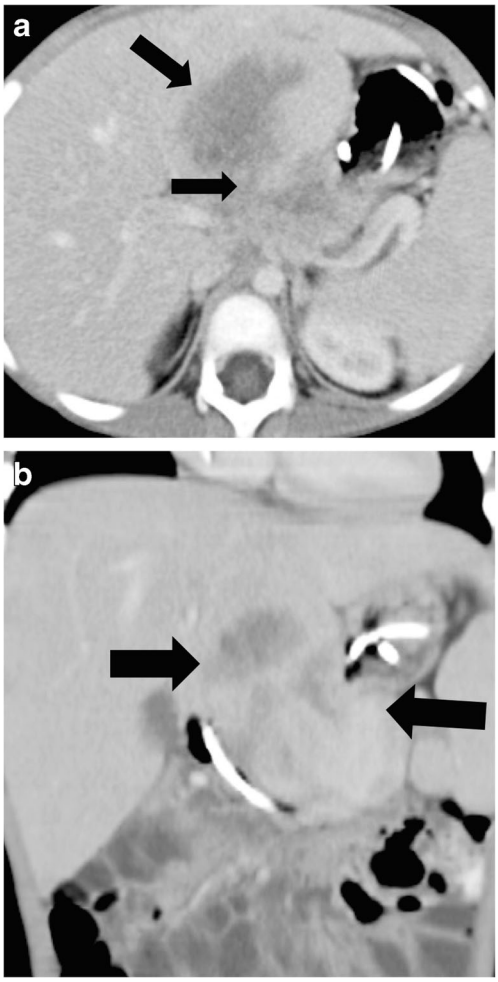

Fig. 8 Inflammatory myofibroblastic tumor in a 5-year-old girl who presented with anorexia, fever, vomiting and anemia. **a**, **b** CT images with intravenous contrast in the axial (**a**) and coronal (**b**) reconstructions demonstrate a hypoattenuating large mass inseparable from the stomach (*arrows*). The mass had eroded the native stomach wall, resulting in chronic bleeding, and ultimately requiring partial gastrectomy for adequate resection

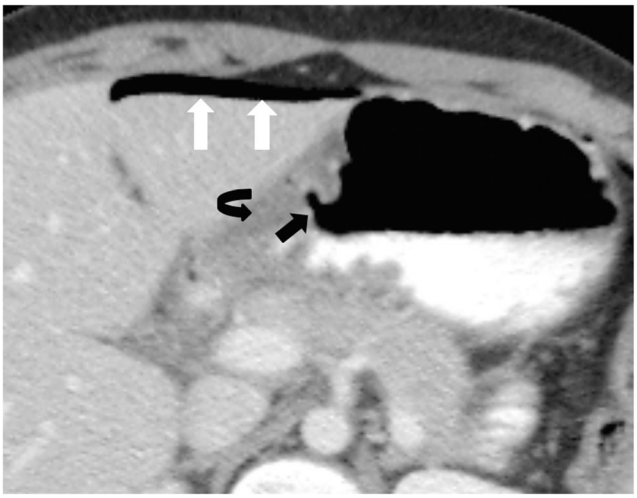

Fig. 9 Perforated gastric ulcer in a 12-year-old boy who presented with abdominal pain. He was initially thought to have appendicitis and underwent laparoscopic appendectomy. The appendix was not inflamed on histological review, and he had persistent abdominal pain. Further evaluation of his presenting CT demonstrates a mucosal crater in the gastric body (*straight black arrow*) surrounded by inflammation, a locule of gas (*curved black arrow*) and perihepatic pneumoperitoneum (*white arrows*). The patient underwent exploratory laparoscopy for a perforated gastric ulcer; the ulcer was covered by a thick fibrinous exudate

prepared formula, but it has also been reported in children fed human milk and cow's milk [47]. The presentation can vary from an acute, surgical abdomen to a simple abdominal distention. If clinical suspicion is high, the diagnosis can be invoked by radiograph, where bubbly lucencies may be identified within the gastric bubble on frontal and decubitus views [48]. US may demonstrate an intraluminal, heterogeneous, echogenic mass [49].

Trichobezoars, in particular, are predominant in young girls with psychiatric comorbidities such as trichotillomania and obsessive-compulsive disorder. Radiographs may show an air-distended stomach surrounding a dense mass. Sonographic features will depend on the bezoar contents. Heterogeneous material in the gastric lumen will be identified; echogenic foci may be evident if calcifications are present. Notably, if anechoic solution is given to the patient during real-time examination, it will circumscribe the immobile bezoar within the gastric lumen, rendering the appearance more conspicuous [50]. In adults, the US features of a bezoar have been characterized as an intraluminal mass with arc-like borders, twinkle artifact, and posterior acoustic shadowing [51]. On CT imaging, enteric contrast will surround but not opacify the bezoar, which is typically heterogeneous, mottled in appearance and contains gas locules (Fig. 10). Depending on chronicity, patients may present with mucosal erosion and ulceration. A critical determination to make on CT is whether a bezoar is confined to the stomach, which may be managed endoscopically, or extends beyond the pylorus into the duodenum and jejunum. This is referred to as Rapunzel syndrome, which often necessitates laparotomy [52].

Crohn disease

Inflammatory bowel disease (IBD), subclassified as Crohn disease, ulcerative colitis or unspecified IBD, is becoming more prevalent in children, with 20–30% of new cases occurring in patients younger than 20 years old. IBD in children is genetically and phenotypically distinct from IBD in adults. Early-onset IBD (ages 6–16 years) and very-early onset (<6 years) IBD have become more prevalent. These entities more typically involve the colon and distal small bowel [53]. Upper gastrointestinal tract involvement in pediatric Crohn disease patients has long been reported [54]. While the overall prevalence of proximal alimentary IBD (esophagus, stomach and duodenum) is estimated to be 0.5–4.0% in the general population [55], it is considered more common in children.

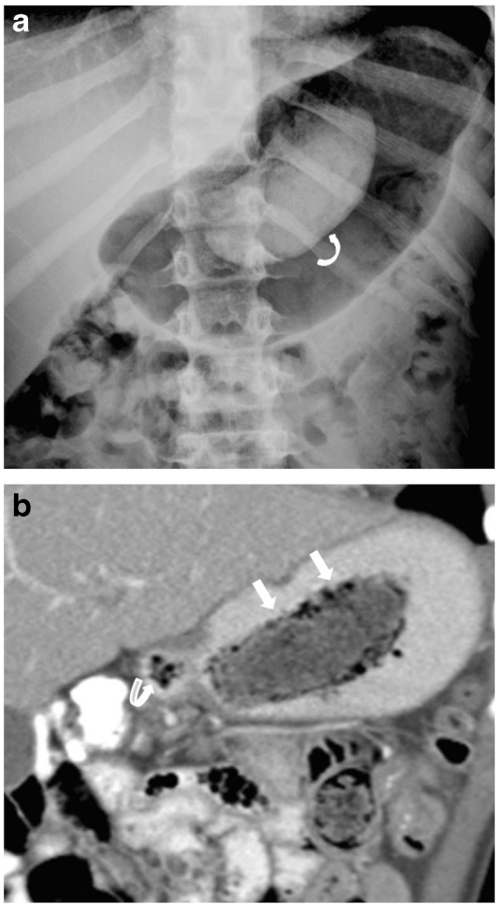

Fig. 10 Bezoar in a 6-year-old girl with abdominal pain. **a** On a supine abdominal radiograph, air rises anteriorly, circumscribing the intraluminal mass (*curved arrow*). **b** A subsequent coronal CT image with intravenous and enteric contrast demonstrates an intraluminal nonenhancing mass with locules of gas, extending across the gastric body (*white straight arrows*) and distal antrum (*white curved arrow*). Enteric contrast surrounds the intraluminal mass. The patient ultimately required gastrotomy to deliver a large trichobezoar

One 7-year, single-institution retrospective analysis of children with IBD evaluated endoscopically reported that 64% of 81 patients with Crohn disease demonstrated upper tract pathology, which most commonly manifested as gastric mucosal granulomas [56]. Because upper tract Crohn disease is more common in children and usually accompanied by distal bowel pathology, it is recommended that children with IBD undergo upper endoscopy to help differentiate between Crohn disease and ulcerative colitis, which rarely has upper tract features [57]. While histological evaluation at gastroscopy is the reference standard, imaging plays an increasingly important role in detecting an abnormal stomach in these patients, especially if it is antecedent to an IBD diagnosis. Gastric Crohn disease usually spares the body but involves the antrum and pylorus. In severe cases, it may manifest fluoroscopically as intraluminal narrowing, or it may present as circumferential wall thickening on CT, mimicking a mass. The findings have been referred to as a ram's horn deformity (Fig. 11) [58, 59].

Foveolar hyperplasia

Patients with cyanotic heart disease may require prostaglandin therapy to maintain the ductus arteriosus in the first days of life. A physiological by-product of this is gastric mucosal hypertrophy, particularly at the antrum. If severe enough, foveolar hypertrophy can cause gastric outlet obstruction and mimic idiopathic hypertrophic pyloric stenosis [60]. US can typically distinguish between hypertrophic pyloric stenosis and foveolar hyperplasia; the presence of both entities in a single patient has been described [61]. In prostaglandin-induced disease, mucus-secreting foveolar cells are stimulated and hypertrophied, which manifests as redundant, heaped-up folds of mucosal tissue (Fig. 12). The muscular wall itself is not thickened [60, 62]. Neonates on prostaglandin infusion should be monitored for signs of gastric outlet obstruction, which abates when prostaglandin therapy is discontinued.

Menetriere disease

Menetriere disease is a form of hypertrophic gastropathy, which, like in foveolar hyperplasia, affects mucin-producing cells. It is exceedingly rare in children. When present, it may

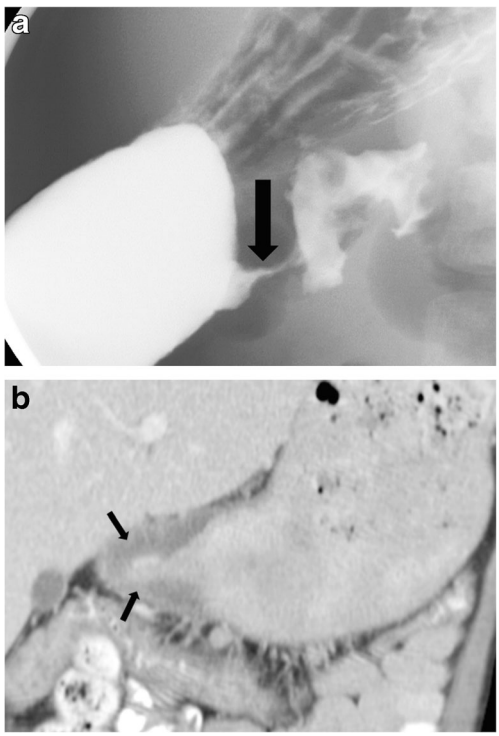

Fig. 11 Inflammatory bowel disease in an 8-year-old girl with a history of anemia, hypoalbuminemia and abdominal pain. **a** Right lateral decubitus fluoroscopic single-contrast view reveals marked caliber narrowing at the antrum of the stomach (*arrow*). **b** Subsequent coronal CT imaging with intravenous and enteric contrast demonstrates pronounced gastric antral and pyloric wall thickening with intraluminal narrowing (*arrows*). This represents the ram's horn deformity of the stomach. The patient was ultimately diagnosed with gastric Crohn disease

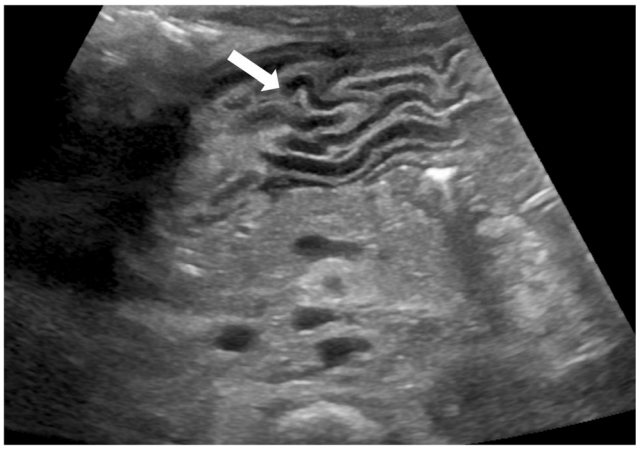

Fig. 12 Foveolar hyperplasia in a 3-month-old boy with congenital cardiac disease, who was receiving chronic prostaglandin therapy, with worsening abdominal distention. Transabdominal sonographic gray-scale imaging of the abdominal midline in the transverse plane demonstrates redundant, heaped-up mucosal tissue in the gastric antrum (*arrow*)

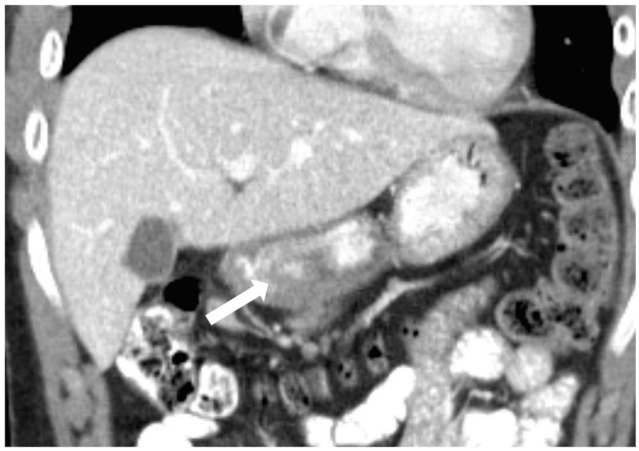

Fig. 13 Eosinophilic gastroenteritis in a 16-year-old boy with chronic abdominal pain and anorexia. CT imaging with intravenous and enteric contrast demonstrates subepithelial mass-like antral thickening in the coronal plane (*arrow*). Endoscopy revealed an ulcerated antral mass, which proved to be eosinophilic gastritis on biopsy. The patient improved after steroid therapy

represent a familial variant or be associated with cytomegalovirus [63, 64]. The sonographic features are similar to those in prostaglandin-induced foveolar hyperplasia, although the antrum is typically spared [63, 65].

Eosinophilic gastroenteritis

Eosinophilic gastroenteritis is an inflammatory disorder characterized by infiltration of eosinophils and activated mast cells within either the intestinal wall mucosal or muscular layers [66]. This condition commonly affects the stomach, particularly in patients with allergies and atopy [67]. Gastric disease may precipitate chronic symptoms such as functional dyspepsia and epigastric pain. Mucosal involvement may cause anemia and melena, whereas muscular involvement may cause gastric outlet obstruction [68]. Ultimately, the diagnosis requires histological confirmation [69]. While the imaging findings of eosinophilic infiltration elsewhere in the alimentary tract have been described [70], the value of imaging for eosinophilic gastroenteritis has been considered limited. However, this pathology is increasingly recognized as underdiagnosed [71]. Radiologists encountering children with abdominal pain and a history of atopy should be aware of this condition. US evaluation may demonstrate hypoechoic submucosal wall thickening [72]. CT may reveal irregular gastric folds and nodular, mass-like thickening (Fig. 13) [73].

Chronic granulomatous disease

Chronic granulomatous disease is a genetic immunodeficiency in which malfunctioning phagocytes result in recurrent infections, usually within the first year of life [74]. This condition can involve the stomach, although respiratory, lymphoid and osseous manifestations are more common. Children with gastrointestinal chronic granulomatous disease present with either vague abdominal pain or gastric outlet obstruction, usually within the first decade of life [75]. US findings are nonspecific. Fluoroscopy may demonstrate circumferential antral wall thickening and luminal narrowing [74, 76]. Chronic granulomatous disease should be considered when these imaging findings are encountered in a young child with repeated bacterial infections.

Conclusion

Primary gastric pathology in infants and children is uncommon. Meaningful imaging evaluation of the pediatric stomach remains challenging, even with cross-sectional imaging, and endoscopy and surgery are often necessary for definitive diagnoses. Nonetheless, some pediatric gastric mass and mass-like conditions have suggestive imaging findings. The pediatric stomach is primarily evaluated dynamically by fluoroscopy, and US, CT, MRI and PET all provide excellent options for multiplanar imaging. These often permit radiologists to provide important diagnostic, anatomical and physiological information before endoscopy or surgery.

Compliance with ethical standards

Conflicts of interest None

References

1. Curtis JL, Burns RC, Wang L et al (2008) Primary gastric tumors of infancy and childhood: 54-year experience at a single institution. J Pediatr Surg 43:1487–1493
2. Iqbal CW, Mortellaro VE, Sharp SW et al (2012) Evaluation of ultrasonographic parameters in the diagnosis of pyloric stenosis. J Surg Res 47:1542–1547
3. Hernanz-Schulman M (2003) Infantile hypertrophic pyloric stenosis. Radiology 227:319–331
4. Menashe SJ, Iyer RS, Parisi MT et al (2017) Pediatric abdominal radiographs: common and less common errors. AJR Am J Roentgenol 209:417–429
5. Callahan MJ, Talmadge JM, MacDougall RD et al (2017) Selecting appropriate gastroenteric contrast media for diagnostic fluoroscopic imaging in infants and children: a practical approach. Pediatr Radiol 47:372–381
6. Hernanz-Schulman M, Goske MJ, Bercha IH, Strauss KJ (2011) Pause and pulse: ten steps that help manage radiation dose during pediatric fluoroscopy. AJR Am J Roentgenol 197:475–481
7. Atkinson NSS, Bryant RV, Dong Y et al (2017) How to perform gastrointestinal ultrasound: anatomy and normal findings. World J Gastroenterol 23:6931–6941
8. Rapaccini GL, Aliotta A, Pompili M et al (1988) Gastric wall thickness in normal and neoplastic subjects: a prospective study performed by abdominal ultrasound. Gastrointest Radiol 13:197–199
9. Deslandes A (2013) Sonographic demonstration of stomach pathology: reviewing the cases. Australas J Ultrasound Med 16:202–209
10. Paolantonio P, Rengo M, Ferrari R, Laghi A (2016) Multidetector CT in emergency radiology: acute and generalized non-traumatic abdominal pain. Br J Radiol 89:20150859
11. Callahan MJ, Talmadge JM, MacDougall R et al (2016) The use of enteric contrast media for diagnostic CT, MRI, and ultrasound in infants and children: a practical approach. AJR Am J Roentgenol 206:973–979
12. Pickhardt PJ, Asher DB (2003) Wall thickening of the gastric antrum as a normal finding: multidetector CT with cadaveric comparison. AJR Am J Roentgenol 181:973–979
13. Desai RK, Tagliabue JR, Wegryn SA, Einstein DM (1991) CT evaluation of wall thickening in the alimentary tract. Radiographics 11:771–783
14. Callahan MJ, MacDougall RD, Bixby SD et al (2018) Ionizing radiation from computed tomography versus anesthesia for magnetic resonance imaging in infants and children: patient safety considerations. Pediatr Radiol 48:21–30
15. Darge K, Anupindi SA, Jaramillo D (2011) MR imaging of the abdomen and pelvis in infants, children, and adolescents. Radiology 261:12–29
16. Järvinen HJ, Sipponen P (1986) Gastroduodenal polyps in familial adenomatous and juvenile polyposis. Endoscopy 18:230–234
17. Islam RS, Patel NC, Lam-Himlin D, Nguyen CC (2013) Gastric polyps: a review of clinical, endoscopic, and histopathologic features and management decisions. Gastroenterol Hepatol 9:640–651
18. Attard TM, Yardley JH, Cuffari C (2002) Gastric polyps in pediatrics: an 18-year hospital-based analysis. Am J Gastroenterol 97:298–301
19. Feczko PJ, Halpert RD, Ackerman LV (1985) Gastric polyps: radiological evaluation and clinical significance. Radiology 155:581–584
20. Choe BK, Kim JY, Hwang JB et al (2006) A case of primary gastric lymphoma in a child. J Pediatr Hematol Oncol 28:296–299
21. Jacquemart C, Guidi O, Etienne I et al (2008) Pediatric gastric lymphoma: a rare entity. J Pediatr Hematol Oncol 30:984–986
22. Devaney K, Jaffe ES (1991) The surgical pathology of gastrointestinal Hodgkin's disease. Am J Clin Pathol 95:794–801
23. Lin YM, Chiu NC, Li AF et al (2017) Unusual gastric tumors and tumor-like lesions: radiological with pathological correlation and literature review. World J Gastroenterol 23:2493–2504
24. Miller FH, Kochman ML, Talamonti MS et al (1997) Gastric cancer. Radiologic staging. Radiol Clin N Am 35:331–349
25. Ghai S, Pattison J, Ghai S et al (2007) Primary gastrointestinal lymphoma: spectrum of imaging findings with pathologic correlation. Radiographics 27:1371–1388
26. Derchi LE, Banderali A, Bossi C et al (1984) The sonographic appearances of gastric lymphoma. J Ultrasound Med 3:251–256
27. Vetro C, Romano A, Amico I et al (2014) Endoscopic features of gastro-intestinal lymphomas: from diagnosis to follow-up. World J Gastroenterol 20:12993–13005
28. Mantese G (2019) Gastrointestinal stromal tumor: epidemiology, diagnosis, and treatment. Curr Opin Gastroenterol 35:555–559
29. Quiroz HJ, Willobee BA, Sussman MS et al (2018) Pediatric gastrointestinal stromal tumors—a review of diagnostic modalities. Transl Gastroenterol Hepatol 3:54
30. Harlan LC, Eisenstein J, Russell MC et al (2015) Gastrointestinal stromal tumors: treatment patterns of a population-based sample. J Surg Oncol 111:702–707
31. Herzberg M, Beer M, Anupindi S et al (2018) Imaging pediatric gastrointestinal stromal tumor (GIST). J Pediatr Surg 53:1862–1870
32. Akram M, Ravikumar N, Azam M et al (2009) Prenatal findings and neonatal immature gastric teratoma. BMJ Case Rep. https://doi.org/10.1136/bcr.10.2008.1050
33. Saleem M, Mirza B, Talat N, Sharif M (2018) Gastric teratoma: our 17 year experience. J Pediatr Surg 53:234–236
34. Kumar S, Yadav H, Rattan KN et al (2016) Immature gastric Teratoma in a newborn: a case report. J Neonatal Surg 5:21
35. Tessler RA, Dellinger M, Richards MK et al (2019) Pediatric gastric adenocarcinoma: a National Cancer Data Base review. J Pediatr Surg 54:1029–1034
36. Lin CH, Lin WC, Lai IH et al (2015) Pediatric gastric cancer presenting with massive ascites. World J Gastroenterol 21:3409–3413
37. Bulbul A, Fahy BN, Xiu J et al (2017) Desmoplastic small round blue cell tumor: a review of treatment and potential therapeutic genomic alterations. Sarcoma 2017:1278268
38. Morani AC, Bathala TK, Surabhi VR et al (2019) Desmoplastic small round cell tumor: imaging pattern of disease at presentation. AJR Am J Roentgenol 212:W45–W54
39. Dufresne A, Cassier P, Couraud L et al (2012) Desmoplastic small round cell tumor: current management and recent findings. Sarcoma 2012:714986
40. Oguz B, Ozcan HN, Omay B et al (2015) Imaging of childhood inflammatory myofibroblastic tumor. Pediatr Radiol 45:1672–1681
41. Karnak I, Senocak ME, Ciftci AO et al (2001) Inflammatory myofibroblastic tumor in children: diagnosis and treatment. J Pediatr Surg 36:908–912
42. Patnana M, Sevrukov AB, Elsayes KM et al (2012) Inflammatory pseudotumor: the great mimicker. AJR Am J Roentgenol 198:W217–W227
43. Narla LD, Newman B, Spottswood SS et al (2003) Inflammatory pseudotumor. Radiographics 23:719–729
44. Kim SJ, Kim WS, Cheon JE et al (2009) Inflammatory myofibroblastic tumors of the abdomen as mimickers of malignancy: imaging features in nine children. AJR Am J Roentgenol 193:1419–1424
45. Hua MC, Kong MS, Lai MW, Luo CC (2007) Perforated peptic ulcer in children: a 20-year experience. J Pediatr Gastroenterol Nutr 45:71–74
46. Iwamuro M, Okada H, Matsueda K et al (2015) Review of the diagnosis and management of gastrointestinal bezoars. World J Gastrointest Endosc 7:336–345

47. DuBose TM 5th, Southgate WM, Hill JG (2001) Lactobezoars: a patient series and literature review. Clin Pediatr 40:603–606
48. Schreiner RL, Brady MS, Franken EA et al (1979) Increased incidence of lactobezoars in low birth weight infants. Am J Dis Child 133:936–940
49. Naik DR, Bolia A, Boon AW (1987) Demonstration of a lactobezoar by ultrasound. Br J Radiol 60:506–508
50. Goff WB 2nd, Kilcheski TS (1984) A gastric bezoar causing a target lesion as revealed by ultrasound. J Ultrasound Med 3:275–276
51. Ripollés T, García-Aguayo J, Martínez MJ, Gil P (2001) Gastrointestinal bezoars: sonographic and CT characteristics. AJR Am J Roentgenol 177:65–69
52. Gorter RR, Kneepkens CM, Mattens EC et al (2010) Management of trichobezoar: case report and literature review. Pediatr Surg Int 26:457–463
53. Crowley E, Muise A (2018) Inflammatory bowel disease: what very early onset disease teaches us. Gastroenterol Clin N Am 47:755–772
54. Mashako MN, Cezard JP, Navarro J et al (1989) Crohn's disease lesions in the upper gastrointestinal tract: correlation between clinical, radiological, endoscopic, and histological features in adolescents and children. J Pediatr Gastroenterol Nutr 8:442–446
55. Pimentel AM, Rocha R, Santana GO (2019) Crohn's disease of esophagus, stomach and duodenum. World J Gastrointest Pharmacol Ther 10:35–49
56. Abdullah BA, Gupta SK, Croffie JM et al (2002) The role of esophagogastroduodenoscopy in the initial evaluation of childhood inflammatory bowel disease: a 7-year study. J Pediatr Gastroenterol Nutr 35:636–640
57. Ooi CJ, Makharia GK, Hilmi I et al (2016) Asia Pacific consensus statements on Crohn's disease. Part 1: definition, diagnosis, and epidemiology. J Gastroenterol Hepatol 31:45–55
58. Farman J, Faegenburg D, Dallemand S, Chen CK (1975) Crohn's disease of the stomach: the "ram's horn" sign. AJR Am J Roentgenol 123:242–251
59. Xiang H, Han J, Ridley WE, Ridley LJ (2018) Ram's Horn Sign: Gastric antrum in Crohn's disease. J Med Imaging Radiat Oncol 62 Suppl 1:101
60. Mercado-Deane MG, Burton EM, Brawley AV, Hatley R (1994) Prostaglandin-induced foveolar hyperplasia simulating pyloric stenosis in an infant with cyanotic heart disease. Pediatr Radiol 24:45–46
61. Callahan MJ, McCauley RG, Patel H, Hijazi ZM (1999) The development of hypertrophic pyloric stenosis in a patient with prostaglandin-induced foveolar hyperplasia. Pediatr Radiol 29: 748–751
62. Peled N, Dagan O, Babyn P et al (1992) Gastric-outlet obstruction induced by prostaglandin therapy in neonates. N Engl J Med 327: 505–510
63. Strisciuglio C, Corleto VD, Brunetti-Pierri N et al (2012) Autosomal dominant Menetrier-like disease. J Pediatr Gastroenterol Nutr 55:717–720
64. Sferra TJ, Pawel BR, Qualman SJ, Li BU (1996) Menetrier disease of childhood: role of cytomegalovirus and transforming growth factor alpha. J Pediatr 128:213–219
65. Friedman J, Platnick J, Farruggia S et al (2009) Ménétrier disease. Radiographics 29:297–301
66. Sunkara T, Rawla P, Yarlagadda KS, Gaduputi V (2019) Eosinophilic gastroenteritis: diagnosis and clinical perspectives. Clin Exp Gastroenterol 12:239–253
67. Mori A, Enweluzo C, Grier D, Badireddy M (2013) Eosinophilic gastroenteritis: review of a rare and treatable disease of the gastrointestinal tract. Case Rep Gastroenterol 7:293–298
68. Koutri E, Papadopoulou A (2018) Eosinophilic gastrointestinal diseases in childhood. Ann Nutr Metab 73(Suppl 4):18–28
69. Licari A, Votto M, D'Auria E et al (2019) Eosinophilic gastrointestinal diseases in children: a practical review. Curr Pediatr Rev. https://doi.org/10.2174/1573396315666191022154432
70. Brandon JL, Schroeder S, Furuta GT et al (2013) CT imaging features of eosinophilic colitis in children. Pediatr Radiol 43:697–702
71. Uppal V, Kreiger P, Kutsch E (2016) Eosinophilic gastroenteritis and colitis: a comprehensive review. Clin Rev Allergy Immunol 50: 175–188
72. Savino A, Salvatore R, Cafarotti A et al (2011) Role of ultrasonography in the diagnosis and follow-up of pediatric eosinophilic gastroenteritis: a case report and review of the literature. Ultraschall Med 32:E57–E62
73. Horton KM, Corl FM, Fishman EK (1999) CT of nonneoplastic diseases of the small bowel: spectrum of disease. J Comput Assist Tomogr 23:417–428
74. Khanna G, Kao SC, Kirby P, Sato Y (2005) Imaging of chronic granulomatous disease in children. Radiographics 25:1183–1195
75. Marciano BE, Rosenzweig SD, Kleiner DE et al (2004) Gastrointestinal involvement in chronic granulomatous disease. Pediatrics 114:462–468
76. Kopen PA, McAlister WH (1984) Upper gastrointestinal and ultrasound examinations of gastric antral involvement in chronic granulomatous disease. Pediatr Radiol 14:91–93