American Journal of Emergency Medicine 82 (2024) 153–160

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

High risk and low incidence diseases: Pediatric digestive volvulus

Brit Long, MD [a,*], Joshua Easter, MD, MSc [b], Alex Koyfman, MD [c]

[a] Department of Emergency Medicine, Brooke Army Medical Center, Fort Sam Houston, TX, USA
[b] Department of Emergency Medicine, University of Virginia School of Medicine, Charlottesville, VA, USA
[c] Department of Emergency Medicine, UT Southwestern, Dallas, TX, USA

ARTICLE INFO

Article history:
Received 24 April 2024
Received in revised form 10 June 2024
Accepted 12 June 2024

Keywords:
Gastrointestinal
Volvulus
Gastric
Midgut
Intestinal
Malrotation
Surgery
Pediatric
Ischemia

ABSTRACT

Introduction: Pediatric digestive volvulus is a serious condition that carries with it a high rate of morbidity and mortality.
Objective: This review highlights the pearls and pitfalls of pediatric digestive volvulus, including the presentation, diagnosis, and management in the emergency department (ED) based on current evidence.
Discussion: Pediatric digestive volvulus is a deadly condition most commonly associated with malrotation. It occurs when the stomach or small intestine twists on itself, resulting in ischemia and potentially strangulation with necrosis and perforation. Presentation differs based on the gastrointestinal (GI) segment affected, degree of twisting, and acuity of the volvulus. Gastric volvulus most commonly presents with retching with or without nonbilious emesis and epigastric distension with pain, while midgut volvulus typically presents with bilious emesis in infants. Patients with GI necrosis and perforation may present with hemodynamic compromise and peritonitis. If suspected, emergent consultation with the pediatric surgery specialist is necessary, and if this is not available, transfer to a center with a pediatric surgeon is recommended. Imaging includes plain radiography, ultrasound, or upper GI series, while treatment includes resuscitation, administration of antibiotics, and emergent surgical decompression and detorsion of the involved segments.
Conclusion: An understanding of pediatric digestive volvulus and its many potential mimics can assist emergency clinicians in diagnosing and managing this deadly disease.

Published by Elsevier Inc.

1. Introduction

This article series addresses high risk but uncommon diseases that are encountered in the emergency department (ED). Much of the primary literature evaluating these conditions is not emergency medicine focused. By their very nature, many of these disease states and clinical presentations have little useful evidence available to guide the emergency physician in diagnosis and management. The format of each article defines the disease or clinical presentation to be reviewed, provides an overview of the extent of what we currently understand, and finally discusses pearls and pitfalls using a question and answer format. This article will discuss pediatric digestive volvulus. This condition's high morbidity and mortality, as well as its variable atypical patient presentations and challenging diagnosis, makes it a high risk but uncommon disease.

1.1. Definition

Digestive volvulus is twisting of the gastrointestinal (GI) tract on itself. Volvulus can affect various GI segments, including the stomach, small intestine, and colon [1-9]. Gastric volvulus is twisting by at least 180 degrees of the stomach on itself due to laxity or absent fixation of the stomach, while midgut volvulus occurs with twisting of the intestine and mesentery around a fixed obstacle [1,2,6,10-13]. Both types of volvulus can result in GI tract ischemia and perforation [1-9]. While digestive volvulus was primarily considered a disease of infancy, this is no longer the case, with all ages affected. This review will discuss pediatric digestive volvulus, with a focus on gastric and midgut volvulus.

1.2. Pathophysiology

Gastric volvulus occurs with twisting of the stomach by at least 180 degrees. It is divided into organoaxial, mesenteroaxial, and combined [2,14-18] (Fig. 1). In the organoaxial form, the stomach rotates on an axis connecting the esophagogastric junction and the pylorus, with the antrum rotating in the opposite direction to the stomach fundus. This is the most common form and is associated with high risk of strangulation and necrosis [14-18]. The second type occurs along the mesenteroaxial axis, which bisects the lesser and greater curvatures of the stomach. The antrum rotates superiorly and anteriorly, resulting in the posterior surface then lying anteriorly. The rotation is most

* Corresponding author at: 3551 Roger Brooke Dr, Fort Sam Houston TX 78234, USA.
E-mail address: Brit.long@yahoo.com (B. Long).

https://doi.org/10.1016/j.ajem.2024.06.012
0735-6757/Published by Elsevier Inc.

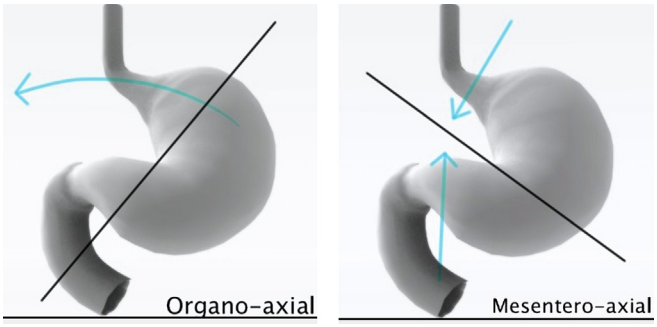

Fig. 1. Types of gastric volvulus. Case courtesy of Maxime St-Amant, Radiopaedia.org, rID: 19257.

commonly incomplete and intermittent, and ischemia is rare [14,17]. The final type is combined, in which the stomach twists along the organoaxial and mesenteroaxial axis [10,14-17]. This is uncommon and most commonly occurs in those with chronic volvulus [16]. Gastric volvulus is further divided into type 1 (idiopathic), which makes up two thirds of cases, and type 2 (acquired or congenital) [2,10,14-18]. Type 1 is thought to be due to abnormal stomach attachments and increased laxity of the gastrosplenic, gastroduodenal, gastrohepatic, and gastrophrenic ligaments. This increased laxity allows for the cardia and pylorus to be approximated when the stomach is full, which can result in volvulus [2,14,18]. Type 2 is most commonly associated with congenital or acquired abnormalities with increased stomach mobility, such as diaphragmatic defects, gastric ligament abnormalities, abnormal attachments or adhesions, asplenism, bowel malformations, pyloric stenosis, and others [2,14,18]. Gastric volvulus may also occur as a complication of gastroesophageal surgery, intra-abdominal tumors, and neuromuscular disorders [2]. No matter the exact type or cause, gastric strangulation may result in necrosis and perforation.

Midgut volvulus occurs with intestinal twisting, most commonly resulting from malrotation. Midgut malrotation occurs when the embryologic sequence for the development, normal rotation, and fixation of the intestines is disrupted, which occurs from weeks 4–12 of gestation [1,2,19-21]. By week 12, the midgut (middle of the duodenum to the splenic flexure of the colon) has normally undergone a 270-degree counterclockwise rotation towards the right. This results in the duodenojejunal junction in the left upper quadrant and the cecum in the right lower quadrant. Following this, the intestines are stabilized by mesenteric attachments. This rotation and fixation result in a wide-based mesentery extending from the ligament of Treitz (left upper quadrant) to the ileocecal valve (right lower quadrant). Any arrest of the rotation may result in abnormal intestinal loops positioning, and stabilization of these loops may not occur. The majority of anomalies cause a narrow mesenteric base, which increases the risk of intestinal twisting and volvulus. In midgut malrotation, the duodenojejunal limb is non-rotated, and the cecocolic limb is partially rotated. This results in the cecum in the mid-upper abdomen, which is fixated to the right lateral abdominal wall by peritoneal bands, known as Ladd's bands [1,2,19,20]. These bands may cross the duodenum and obstruct the duodenum. Other rotational abnormalities are less common and include reverse rotation of the duodenojejunal limb, reverse rotation of the cecocolic limb, and reverse rotation of the duodenojejunal limb with normal rotation of the cecocolic limb [1,2,19]. Ultimately, intestinal twisting may result in volvulus with strangulation, necrosis, and perforation if not treated.

1.3. Epidemiology

The true incidence of gastric and midgut volvulus is unknown due to the variety of presentations and high likelihood of underdiagnosis [1,2,6,20,22]. Gastric volvulus is less common than midgut volvulus in the pediatric population, with 581 cases of gastric volvulus reported between 1929 and 2007 [22]. Males and females are affected equally, with 10–20% of cases occurring in children (typically before 1 year of age) [2,14-18,22-27]. The mortality rate of gastric volvulus previously ranged between 30 and 80%, but with more recent advances, the mortality rate has decreased to <20% [15-17,23-27]. The most common cause of death in gastric volvulus is strangulation resulting in necrosis with perforation, which occurs in 5–28% of those with organoaxial gastric volvulus [15,16].

Symptomatic neonatal malrotation occurs in 1 of every 6000 live births, which places patients at significant risk for digestive volvulus [1-3,28-32]. Many patients with small intestine malrotation have an associated abnormality such as congenital diaphragmatic hernia, congenital heart disease, gastroschisis, omphalocele, prune-belly syndrome, intestinal and esophageal atresias, biliary atresia, Meckel diverticulum, complex anorectal malformations, or Cornelia de Lange syndrome [5,7,9,20,21,32-47]. Importantly, as malrotation is the most common contributor to midgut volvulus, the majority of cases occur in the neonatal/infant period, and midgut volvulus is one of the most common causes of an acute abdomen in this population [1-3,12,13,21,30,32]. Approximately 80% of cases of midgut volvulus present in the first month following birth, with 90% occurring in the first year [6,21]. Mortality for midgut volvulus ranges between 3 and 16% [1,2,6,28,30].

2. Discussion

2.1. ED presentation

The presentation of volvulus is dependent on which segment of the GI tract is involved. Gastric volvulus often presents with retching without emesis or non-bilious emesis, as well as abdominal distension [2,14-18,22-27]. The failure to pass a nasogastric tube, retching without emesis, and abdominal pain and distension, known as Borchardt's triad, is classically associated with gastric volvulus but is not present in all cases [2,3,14-18,26,27].

The most frequent presentation of midgut volvulus includes vomiting, occurring in over 90% of those <1 month of age [1-3,6,30,41,48-50]. This emesis is typically bilious (green or fluorescent yellow), though it may be nonbilious [6,30,41,48-50]. Volvulus should be considered in all infants with bilious emesis until proven otherwise. While most cases present with acute pain and vomiting, some patients may have intermittent volvulus with chronic, episodic vomiting and abdominal pain over months to years [6,30,37-41]. Acute, severe vomiting may result in hypovolemia. Abdominal pain is more common in older patients, while neonates and infants may demonstrate lethargy, fussiness, and decreased feeding [6,30,42-50]. Older patients may also present with constipation [6,28,42-48]. Examination may reveal complications including hemodynamic instability (hypovolemia, septic shock), fever (sepsis), abdominal distension and/or tenderness, peritonitis (indicating perforation), and hematochezia [1-3,6].

2.2. ED diagnosis

The clinician should suspect digestive volvulus in any infant with bilious emesis. It should also be considered in children with vomiting and a condition known to be associated with malrotation, pediatric patients with hemodynamic instability and abdominal pain or vomiting, and pediatric patients with severe abdominal pain out of proportion to the examination [1-3,6,30]. If a high pretest probability of digestive volvulus is present, emergent consultation with the pediatric surgical specialist, prior to any imaging, is recommended to assist with further treatment and management [1-3,6,30]. If a pediatric surgical specialist is not available, transfer to a center with a pediatric surgeon is recommended.

Imaging for gastric volvulus may include plain radiography, upper GI series, or ultrasound (US). Plain radiographs may be performed for patients with suspected gastric volvulus. These may demonstrate a horizontal stomach with single air-fluid level in those with organoaxial volvulus [16,26,27,51]. In mesenteroaxial volvulus, the clinician may see a spherical stomach on supine radiographs and two air-fluid levels with the antrum superior to the fundus [16]. Upper GI contrast series is the diagnostic modality of choice for gastric volvulus [14-18,24,51-54]. US can also be used to evaluate for gastric volvulus and associated anatomical abnormalities [2,55-60].

If the patient is stable and midgut volvulus is suspected, plain radiography, upper GI series, or abdominal US should be performed, though upper GI series with contrast is classically considered the gold standard for diagnosis [55-70]. Plain radiography may reveal two or three air-fluid levels with no gas in the distal small intestine, a gasless abdomen, or double bubble sign similar to duodenal atresia [1,2,6,70]. Plain radiographs are not sufficiently sensitive to rule out volvulus in an infant with bilious emesis, as they are often normal early in the disease process [1,61,62]. Children with ischemia may show signs of pneumatosis intestinalis on radiographs, which might be confused for necrotizing enterocolitis. US may reveal abnormal position of the duodenum and superior mesenteric vein (SMV), the whirlpool sign (vessels twisting around the mesenteric pedicle base), fixed midline bowel, or dilated duodenum [56,57,61-71]. If US is performed first and is negative but clinical suspicion remains, upper GI series should be obtained [61,62,66,68,71]. This may reveal a displaced duodenum with the duodenojejunal junction located to the right of the left vertebral pedicles, corkscrew appearance of the duodenum, or duodenal obstruction with a beaklike tapering of contrast in the bowel. If equivocal, further imaging may include small bowel follow-through with repeated upper GI contrast study or a contrast enema to assess the location of the cecum, which is abnormal in 80% of patients with malrotation [61,62,70-73]. False positives may arise in normal children <4 years of age due to variation in the location of the duodenojejunal junction [74]. Other imaging tests include computed tomography (CT), magnetic resonance imaging (MRI), and laparotomy [75-78]. Importantly, no diagnostic study has sufficient sensitivity to rule out midgut volvulus, and pediatric surgical consultation is typically appropriate for all concerning patients regardless of imaging findings [1,2,6].

2.3. ED management

Emergent consultation with the pediatric surgical specialist is necessary if volvulus is suspected on initial evaluation or confirmed with imaging. The emergency clinician should resuscitate as needed with intravenous (IV) fluids due to the risk of severe hypovolemia [1,3-6]. Administration of IV broad-spectrum antibiotics covering bowel flora (piperacillin-tazobactam or ceftriaxone with metronidazole) is recommended, as well as cautious placement of an oro or nasogastric tube to decompress the GI system [1-4,6]. Of note, some cases may require imaging or endoscopic guidance for GI decompression. Aggressive tube placement is not recommended, as it may result in perforation [18]. Gastric volvulus requires operative intervention for surgical reduction, correction of the underlying cause, and gastropexy [2]. Patients with midgut volvulus require emergent laparotomy with detorsion of the volvulus and the Ladd procedure [1-4,6]. In those with malrotation found incidentally, elective surgical repair may be pursued [1,2]. However, midgut malrotation is managed surgically in almost all pediatric patients with the Ladd procedure, which entails widening the mesentery base, placing the bowel in a nonrotation position, and making adhesions to fix the intestines in place [1-4,6].

3. Pearls and pitfalls

3.1. What are the risk factors for gastric and midgut volvulus, and what are the most common associated conditions?

There are a variety of risk factors and conditions associated with digestive malrotation with volvulus. Congenital abnormalities are present in 30–100% of patients [5,7,9,20,21,32-47]. The most common is congenital diaphragmatic hernia. Congenital heart disease is present in 40–90%, and omphalocele occurs in up to 45% [5,7,9,31,33]. Intestinal atresia or web is also common in patients with malrotation. Other associations include Meckel diverticulum, Hirschsprung disease, intussusception, mesenteric cyst, extrahepatic biliary system abnormalities, complex anorectal malformations, and Cornelia de Lange syndrome [5,7,9,20,21,32-47]. While not all patients with malrotation and volvulus will have an associated risk factor, the presence of one of the aforementioned associations should raise clinical suspicion in the appropriate setting (e.g., abdominal pain, nausea, vomiting).

Primary gastric volvulus is more likely in those with stomach laxity or lack of physiological fixation [2,10,11,14-18]. Secondary causes of gastric volvulus are more common in those with factors that increase gastric mobility, such as gastric distension, gastric ligament defects, diaphragmatic hernia or other defects, bowel malformations, intestinal malrotation, peritoneal adhesions, pyloric stenosis, and asplenism or wandering spleen [2,79-84]. Midgut volvulus is commonly associated with Ladd's adhesions between the second part of the duodenum and the cecum. However, up to 26% of cases are idiopathic, and it may also be secondary to postoperative adhesions, Meckel's diverticulum, digestive duplications, lipomas, meconium ileus, and cystic hygroma [2,6,85-90].

3.2. How does the history and examination differ between gastric and midgut volvulus?

Gastric volvulus and midgut volvulus can differ in presentation, based on the age affected, the degree of twisting, and the rapidity of the onset. The acute form of gastric volvulus classically presents with Borchardt's triad, which is retching, epigastric distension, and difficulty passing a nasogastric tube [2,14-18,26,27]. While the triad was initially reported to be present in up to 70% of cases, its absence should not be used to exclude the diagnosis [18]. The most common sign is retching or non-bilious vomiting, as the obstruction is proximal to the duodenum [2,14-18,26,27]. Progressive abdominal and epigastric distension is common in these patients, but abdominal findings including distension or tenderness may not be present if the stomach is intrathoracic [2]. Of note, one study reported hiccups to be a subtle sign of gastric volvulus [91]. Hematemesis may be present in the setting of gastric ischemia and bleeding, which may result in severe bleeding and hemodynamic compromise [2,26,27,92].

Patients with midgut volvulus classically present with bilious emesis and initially a flat abdomen that then becomes distended [1,2,6,30]. Up to 93% of patients with midgut volvulus present with vomiting [1,2,6,30]. Abdominal pain is typically present in both types of volvulus. Hematemesis or hematochezia suggest ischemia. With continued ischemia, the patient will develop evidence of sepsis (e.g., fever, tachycardia, hypotension) and peritonitis. Fluid loss from vomiting and third spacing due to intestinal necrosis can result in cardiovascular decompensation and shock [1-4,6]. Incomplete volvulus may present with anorexia, nausea, recurrent abdominal pain, and growth failure, which may occur over weeks to even months [1-4,6].

3.3. What imaging is recommended for gastric volvulus versus midgut volvulus?

For patients with hemodynamic instability or evidence of peritonitis (i.e., abdominal tenderness with rigidity or distension, hematemesis, hematochezia), resuscitation with IV fluids and broad-spectrum antibiotics and pediatric surgical consultation for operative intervention is necessary without imaging confirmation [1-3,6]. In patients without evidence of hemodynamic instability or peritonitis, imaging can confirm the diagnosis of gastric or midgut volvulus [2,6,61,62]. Evaluation for gastric volvulus includes plain radiography of the abdomen and chest, which may reveal two fluid volumes (lowest at the fundus and highest at the antrum) and a spherical stomach for an erect abdominal radiograph with mesenteroaxial gastric volvulus (Fig. 2) [2]. In those with organoaxial gastric volvulus, the stomach will be horizontal with one fluid level. The upper GI contrast series is the recommended imaging modality for definitive diagnosis of gastric volvulus, which demonstrates high sensitivity and specificity [2,24,52,53,61,62,79]. Contrast series demonstrate an overall diagnostic yield of 81–84% [2,24,52,53,61,62,79]. In those with mesenteroaxial volvulus, upper GI contrast series will reveal a pylorus above the gastroesophageal junction. In organoaxial volvulus, the stomach will be horizontal, and the lesser curvature will be under the greater curvature and the gastric pylorus oriented in a downward direction (Figs. 3, 4) [2,79].

Imaging for midgut volvulus includes plain radiography, US, or GI contrast series. The American College of Radiology (ACR) appropriateness criteria recommendations are based on age [61,62]. For patients within the first two days of birth, plain radiography is the recommended first-line modality, evaluating for a double-bubble or triple-bubble sign with no gas within the distal small intestine [61,62]. However, a normal abdominal radiograph does not exclude malrotation or volvulus. For those older than two days, or if plain radiography is not diagnostic, upper GI series is recommended [61,62]. Literature suggests the sensitivity and specificity of upper GI series range between 85 and 95% for diagnosis of midgut volvulus [68-70,93-96]. Factors associated with volvulus on upper GI series include the location of the pylorus, duodenum, and jejunum; angularity or kinking of intestinal loops; unusual redundancy; and relationship between the SMV and superior mesenteric artery (SMA) [71,76,97]. Upper GI series may demonstrate a duodenojejunal junction displaced right and downward on the frontal view, a duodenum with abnormal course on the lateral view, an abnormally positioned jejunum on the right of the abdomen, dilated and fluid-filled duodenum, proximal small intestine obstruction, proximal jejunum spiraling down in the right or mid upper abdomen (corkscrew pattern), and mural edema and thick folds [2,71,76,97] (Figs. 5, 6). Of note, upper GI series demonstrates the highest sensitivity and specificity at pediatric centers with experienced radiologists. If the upper GI series is nondiagnostic but clinical concern remains, the study may be repeated using a nasogastric tube [2,6].

Fig. 2. Plain radiography with frontal view of the abdomen demonstrating the double bubble sign. https://commons.wikimedia.org/wiki/File:Radiograph_with_Double_Bubble_Sign.jpg.

US may be utilized as well for diagnosis and is the first line imaging modality at many institutions [55-59,67]. US may demonstrate reversal of the SMA and SMV and the whirlpool sign, which is clockwise rotation of the SMV, mesentery, and small intestine loops around the SMA (Fig. 7) [55-59,67]. Other findings include the third portion of the duodenum anterior to the SMA, abnormal position of the cecum, hypoplastic uncinate process, a cutoff of the SMA, tapering/beaking of the third portion of the duodenum, dilated proximal duodenum, mesenteric edema, and ascites [55-59,67]. A review of the literature published in 2022 examined US and upper GI series for diagnosis of midgut volvulus [56]. This review reported a sensitivity of 83–100% for US diagnosis with a specificity ranging between 91 and 100%, while the sensitivity and specificity of upper GI series for diagnosis of volvulus was 54–79% and 98%, respectively [56,59,64,67,70,98-108]. The ACR notes limited evidence for US diagnosis of volvulus, and a negative US should not be used to exclude midgut volvulus, though literature suggests high sensitivity and specificity [56,57,60-62,70,109]. Two retrospective series have found a 2–3% false negative rate with US, with upper GI series later confirming the diagnosis [64,101].

The choice between upper GI series and US should be based on local expertise and available resources (e.g., imaging capabilities, access to pediatric surgeon). Thus, consultation with the radiologist is recommended, as well as the pediatric surgeon. Importantly, if there is no access to a pediatric surgeon or experienced radiologist, patients with a high degree of suspicion for volvulus (e.g., bilious emesis in a neonate) should be emergently transferred to a facility with a pediatric surgeon without delays for imaging acquisition. If imaging is obtained and US is diagnostic, an upper GI series is not necessary. If the US is nondiagnostic, then upper GI series should be obtained. Finally, CT with IV contrast or laparoscopy may be used for diagnosis [2,28,76,78,94,110]. CT with IV contrast may demonstrate proximal bowel to the right of the midline, the whirlpool sign, abnormal position of the SMV, and a third part of the duodenum that does not pass between the aorta and the SMA [76,78,94,110,111]. However, CT is not typically obtained in infants. Ultimately, there is no diagnostic study with sufficient sensitivity to definitely exclude volvulus, and thus, pediatric surgical consultation is typically appropriate for all concerning patients.

3.4. What is the management of gastric and midgut volvulus in the ED, and what are potential pitfalls?

All patients with digestive volvulus should receive emergent pediatric surgical consultation due to the risk of ischemia and perforation. Resuscitation with IV fluids is often appropriate due to volume loss and third spacing [1-3,6,33]. Broad-spectrum antibiotics are necessary covering enteric organisms. These may include piperacillin-tazobactam or ceftriaxone with metronidazole [1-3,6,33]. Emergent decompression with a nasogastric or orogastric tube is recommended in gastric and midgut volvulus, though this should be completed with caution due to the risk of perforation, particularly with gastric volvulus [18]. In those with gastric volvulus, surgical intervention includes reduction of the volvulus, assessment of gastric viability with resection of gangrenous

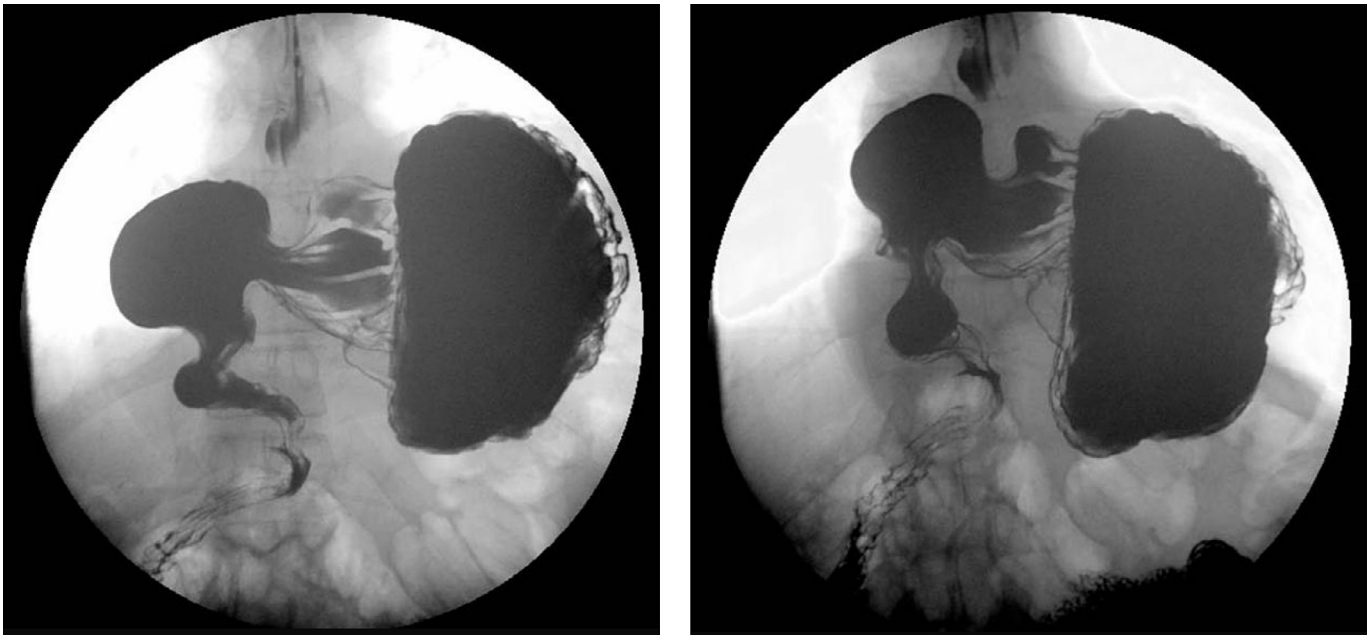

Fig. 3. Organoaxial gastric volvulus, barium study. Case courtesy of The Radswiki, Radiopaedia.org, rID: 11449.

gastric portions, prevention of recurrence with gastropexy, and potentially fundoplication. Minimally invasive approaches are available, including laparoscopy and endoscopy [2,23,24,79,112-124]. Surgical intervention for midgut volvulus includes emergent laparotomy and detorsion of the volvulus, followed by the Ladd procedure [1-4,6]. This includes widening the mesentery base, placing the small intestine in a non-rotated position, and creating adhesions to keep the small intestine in place [1-4,6].

3.5. What are the long-term complications after surgically treated volvulus?

Operative intervention is successful in 89% of patients with volvulus, and the mortality rate for patients after surgery is 3–10% [1-4,6,30,39,125-127]. Mortality rates are higher in patients with intestinal necrosis, prematurity, or associated anomalies [30,39,125]. These rates are lower in otherwise healthy children and no intestinal ischemia. The risk of recurrent midgut volvulus is 3.5% for patients undergoing

Fig. 4. Gastric organoaxial volvulus. Case courtesy of Ahmed Abdrabou, Radiopaedia.org, rID: 24356.

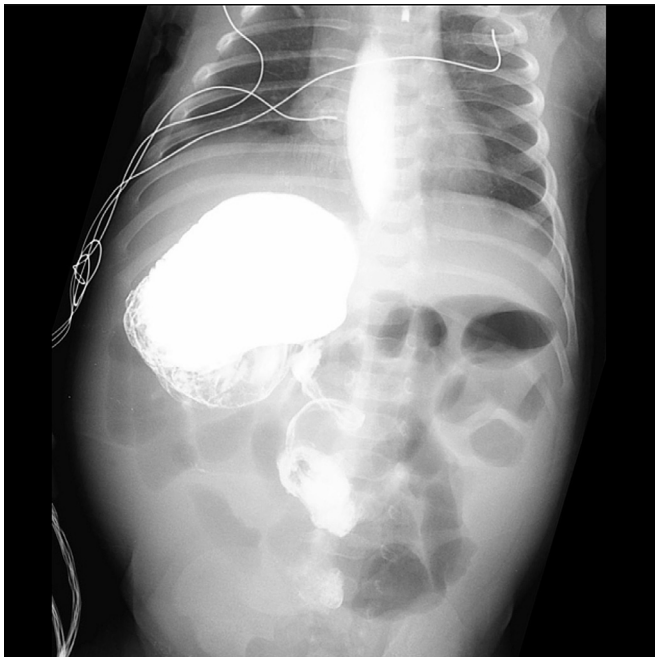

Fig. 5. Corkscrew sign of malrotation with midgut volvulus in an infant. Spot film from a single contrast barium study demonstrates a corkscrew appearance of the fourth portion of the duodenum and the proximal jejunum and an abnormal position of the duodenojejunal junction. Case courtesy of Behrang Amini, Radiopaedia.org, rID: 35920.

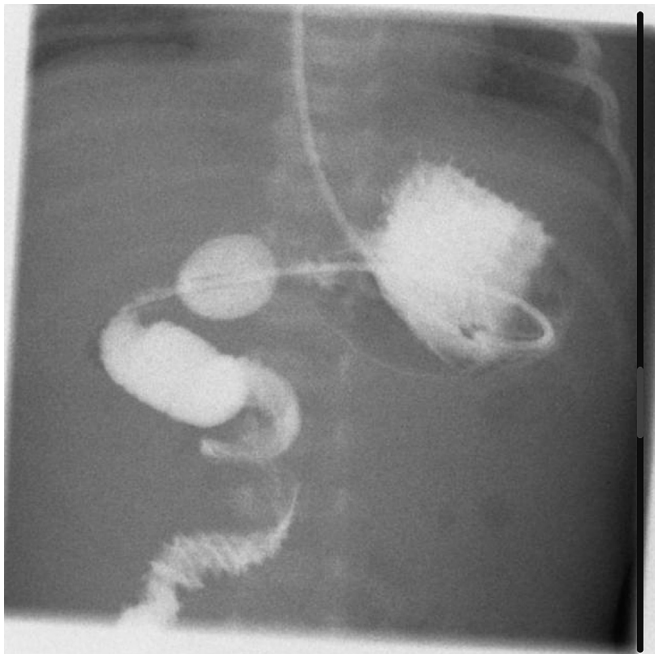

Fig. 6. Contrast demonstrates a malplaced DJ flexure and a corkscrew appearance of the jejunum. This confirms both malrotation and volvulus. Case courtesy of Jeremy Jones, Radiopaedia.org, rID: 8078.

Table 1
Pediatric digestive volvulus pearls.

- Digestive volvulus occurs when a segment of the GI system twists on itself, potentially leading to strangulation, ischemia, and necrosis.
- Gastric volvulus is less common than midgut volvulus, with 10–20% of cases affecting children. Midgut volvulus most commonly affects infants and is associated with malrotation, as well as other congenital abnormalities.
- Presentation differs between gastric and midgut volvulus. The classic presentation of gastric volvulus includes retching, epigastric distension, and difficulty passing a nasogastric tube, though patients may have nonbilious emesis. Midgut volvulus most commonly presents with bilious emesis in an infant.
- The emergency clinician should suspect digestive volvulus in any pediatric patient, particularly an infant, with bilious emesis, those with vomiting and a condition known to be associated with malrotation, pediatric patients with hemodynamic instability and an abdominal complaint, and pediatric patients with severe abdominal pain out of proportion to the examination.
- Emergent consultation with a pediatric surgeon, along with the radiologist, is recommended as soon as the disease is suspected. If a pediatric surgical specialist is not available, transfer to a center with pediatric surgical capability is recommended.
- Imaging should be based on local resources and expertise. Initial imaging for gastric volvulus may include radiography, but upper GI series is the imaging modality of choice. Imaging for midgut volvulus may include US or upper GI series. However, no imaging modality has sufficient sensitivity to rule out midgut volvulus in an infant with bilious emesis.
- All patients require emergent pediatric surgical consultation. Fluid resuscitation is often necessary due to volume loss and third spacing. Broad-spectrum antibiotics should cover enteric organisms. Surgical intervention with emergent laparotomy and detorsion of the volvulus is the definitive therapy. A nasogastric or orogastric tube should be placed with caution if attempted in the ED setting due to the risk of perforation.

laparoscopic intervention and 1.4% for those undergoing the Ladd procedure [1-4,6,30,39,125-128].

Table 1 lists pearls and pitfalls in the evaluation and management of pediatric digestive volvulus.

4. Conclusions

Pediatric digestive volvulus is a dangerous condition associated with twisting of the stomach or small intestine on itself. Gastric volvulus most commonly presents with retching with or without nonbilious emesis and abdominal distension with pain, and passing a nasogastric tube may be difficult. Midgut volvulus typically presents with bilious emesis in infants. Patients may experience hemodynamic compromise and peritonitis with perforation. Emergency clinicians should emergently consult the pediatric surgeon. Imaging includes radiography, US, and upper GI series, though testing should be based on local resources and experience. ED treatment includes resuscitation, broad-spectrum antibiotics, and emergent decompression.

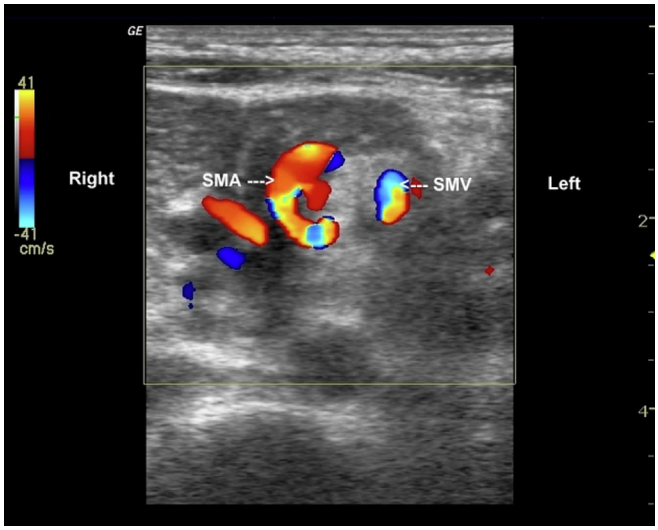

Fig. 7. US with midgut volvulus. Grey scale and color Doppler US through the upper abdomen show whirling vessels and surrounding small bowel loops on transverse scan and corkscrew appearance on longitudinal scan. SMA-SMV relation is reversed. Case courtesy of KewalArunkumar Mistry, Radiopaedia.org, rID: 34790.

CRediT authorship contribution statement

Brit Long: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Data curation, Conceptualization. **Joshua Easter:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Conceptualization. **Alex Koyfman:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Conceptualization.

Declaration of competing interest

None.

Acknowledgements

BL, JE, and AK conceived the idea for this manuscript and contributed substantially to the writing and editing of the review. This manuscript did not utilize any grants, and it has not been presented in abstract form. This clinical review has not been published, it is not under consideration for publication elsewhere, its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. This review does not reflect the views or opinions of the U.S. government, Department of Defense, Defense Health Agency, U.S. Army, U.S. Air Force, or SAUSHEC EM Residency Program.

References

[1] Langer JC. Intestinal rotation abnormalities and midgut volvulus. Surg Clin North Am. 2017 Feb;97(1):147–59.
[2] Garel C, Blouet M, Belloy F, Petit T, Pelage JP. Diagnosis of pediatric gastric, small-bowel and colonic volvulus. Pediatr Radiol. 2016 Jan;46(1):130–8.
[3] Do WS, Lillehei CW. Malrotation: Management of Disorders of gut rotation for the general surgeon. Surg Clin North Am. 2022 Oct;102(5):837–45.
[4] Williams BS, Huynh TA, Mahmoud A. Gastric, duodenal, and small bowel emergencies. Surg Clin North Am. 2023 Dec;103(6):1097–112.
[5] Adams SD, Stanton MP. Malrotation and intestinal atresias. Early Hum Dev. 2014 Dec;90(12):921–5.
[6] Shalaby MS, Kuti K, Walker G. Intestinal malrotation and volvulus in infants and children. BMJ. 2013 Nov;26(347):f6949.
[7] Filston HC, Kirks DR. Malrotation - the ubiquitous anomaly. J Pediatr Surg. 1981 Aug;16(4 Suppl 1):614–20.
[8] KIESEWETTER WB, SMITH JW. Malrotation of the midgut in infancy and childhood. AMA Arch Surg 1958 Oct;77(4):483–91.
[9] Ford EG, Senac Jr MO, Srikanth MS, Weitzman JJ. Malrotation of the intestine in children. Ann Surg. 1992 Feb;215(2):172–8.
[10] Jain P, Sanghavi B, Sanghani H, et al. Congenital diaphragmatic hernia with gastric volvulus. Indian J Surg. 2007;69:260–3.
[11] Porcaro F, Mattioli G, Romano C. Pediatric gastric volvulus: diagnostic and clinical approach. Case Rep Gastroenterol. 2013;7:63–8.
[12] Esposito F, Vitale V, Noviello D, et al. Ultrasonographic diagnosis of midgut volvulus with malrotation in children. J Pediatr Gastroenterol Nutr. 2014;59:786–8.
[13] Valsdottir E, Marks J. Volvulus: small bowel and colon. Clin Colon Rectal Surg. 2008; 21:91–3.
[14] Milne LW, Hunter JJ, Anshus JS, Rosen P. Gastric volvulus: two cases and a review of the literature. J Emerg Med. 1994 May-Jun;12(3):299–306.
[15] Carter R, Brewer 3rd LA, Hinshaw DB. Acute gastric volvulus. A study of 25 cases. Am J Surg. 1980 Jul;140(1):99–106.
[16] Wasselle JA, Norman J. Acute gastric volvulus: pathogenesis, diagnosis, and treatment. Am J Gastroenterol. 1993 Oct;88(10):1780–4.
[17] Rashid F, Thangarajah T, Mulvey D, et al. A review article on gastric volvulus: a challenge to diagnosis and management. Int J Surg. 2010;8(1):18–24.
[18] Miller DL, Pasquale MD, Seneca RP, Hodin E. Gastric volvulus in the pediatric population. Arch Surg. 1991 Sep;126(9):1146–9.
[19] Soffers JH, Hidspoors JP, Mekonen HK, et al. The growth pattern of the human intestine and its mesentery. BMC Dev Biol. 2015;15:31.
[20] Martin V, Shaw-Smith C. Review of genetic factors in intestinal malrotation. Pediatr Surg Int. 2010;26:769–81.
[21] Peterson C, Anderson J, Hara A, et al. Volvulus of the gastrointestinal tract: appearances at multimodality Imaging. Radiographics. 2009;29(5):1281–93.
[22] Cribbs RK, Gow KW, Wulkan ML. Gastric volvulus in infants and children. Pediatrics. 2008;122:e752–62.
[23] Palanivelu C, Rangarajan M, Shetty AR, Senthilkumar R. Laparoscopic suture gastropexy for gastric volvulus: a report of 14 cases. Surg Endosc. 2007 Jun;21 (6):863–6.
[24] Teague WJ, Ackroyd R, Watson DI, Devitt PG. Changing patterns in the management of gastric volvulus over 14 years. Br J Surg. 2000 Mar;87(3):358–61.
[25] Katkhouda N, Mavor E, Achanta K, et al. Laparoscopic repair of chronic intrathoracic gastric volvulus. Surgery. 2000 Nov;128(5):784–90.
[26] Cameron AE, Howard ER. Gastric volvulus in childhood. J Pediatr Surg. 1987 Oct;22 (10):944–7.
[27] El-Gohary MA, Etiaby A. Gastric volvulus in infants and children. Pediatr Surg Int. 1994;9:486–8.
[28] Kanellos-Becker I, Bergholz R, Reinshagen K, Boettcher M. Early prediction of complex midgut volvulus in neonates and infants. Pediatr Surg Int. 2014 Jun;30(6): 579–86.
[29] Aboagye J, Goldstein SD, Salazar JH, et al. Age at presentation of common pediatric surgical conditions: reexamining dogma. J Pediatr Surg. 2014 Jun;49(6):995–9.
[30] Nehra D, Goldstein AM. Intestinal malrotation: varied clinical presentation from infancy through adulthood. Surgery. 2011 Mar;149(3):386–93.
[31] Stewart DR, Colodny AL, Daggett WC. Malrotation of the bowel in infants and children: a 15 year review. Surgery. 1976 Jun;79(6):716–20.
[32] Martinez-Leo B, Chesley P, Alam S, et al. The association of the severity of anorectal malformations and intestinal malrotation. J Pediatr Surg. 2016 Aug;51(8):1241–5.
[33] Graziano K, Islam S, Dasgupta R, et al. Asymptomatic malrotation: diagnosis and surgical management: an American Pediatric surgical association outcomes and evidence based practice committee systematic review. J Pediatr Surg. 2015 Oct;50 (10):1783–90.
[34] Pachl M, Eaton S, Kiely EM, et al. Esophageal atresia and malrotation: what association? Pediatr Surg Int. 2015 Feb;31(2):181–5.
[35] Aslanabadi S, Ghalehgolab-Behbahan A, Jamshidi M, et al. Intestinal malrotations: a review and report of thirty cases. Folia Morphol. 2007 Nov;66(4):277–82.
[36] Chesley PM, Melzer L, Bradford MC, Avansino JR. Association of anorectal malformation and intestinal malrotation. Am J Surg. 2015 May;209(5):907–11. discussion 912.
[37] von Flüe M, Herzog U, Ackermann C, et al. Acute and chronic presentation of intestinal nonrotation in adults. Dis Colon Rectum. 1994 Feb;37(2):192–8.
[38] Pickhardt PJ, Bhalla S. Intestinal malrotation in adolescents and adults: spectrum of clinical and imaging features. AJR Am J Roentgenol. 2002 Dec;179(6):1429–35.
[39] Rescorla FJ, Shedd FJ, Grosfeld JL, et al. Anomalies of intestinal rotation in childhood: analysis of 447 cases. Surgery. 1990 Oct;108(4):710–5. discussion 715–6.
[40] Powell DM, Othersen HB, Smith CD. Malrotation of the intestines in children: the effect of age on presentation and therapy. J Pediatr Surg. 1989 Aug;24(8):777–80.
[41] Lin JN, Lou CC, Wang KL. Intestinal malrotation and midgut volvulus: a 15-year review. J Formos Med Assoc. 1995 Apr;94(4):178–81.
[42] Prasil P, Flageole H, Shaw KS, et al. Should malrotation in children be treated differently according to age? J Pediatr Surg. 2000 May;35(5):756–8.
[43] Kirby CP, Freeman JK, Ford WD, et al. Malrotation with recurrent volvulus presenting with cholestasis, pruritus, and pancreatitis. Pediatr Surg Int. 2000;16(1–2): 130–1.
[44] Spigland N, Brandt ML, Yazbeck S. Malrotation presenting beyond the neonatal period. J Pediatr Surg. 1990 Nov;25(11):1139–42.
[45] Brandt ML, Pokorny WJ, McGill CW, Harberg FJ. Late presentations of midgut malrotation in children. Am J Surg. 1985 Dec;150(6):767–71.
[46] Yanez R, Spitz L. Intestinal malrotation presenting outside the neonatal period. Arch Dis Child. 1986 Jul;61(7):682–5.
[47] Kullendorff CM, Mikaelsson C, Ivancev K. Malrotation in children with symptoms of gastrointestinal allergy and psychosomatic abdominal pain. Acta Paediatr Scand. 1985 Mar;74(2):296–9.
[48] Cullis PS, Mullan E, Jackson A, et al. An audit of bilious vomiting in term neonates referred for pediatric surgical assessment: can we reduce unnecessary transfers? J Pediatr Surg. 2018;53(11):2123–7.
[49] Godbole P, Stringer MD. Bilious vomiting in the newborn: how often is it pathologic? J Pediatr Surg. 2002;37(6):909–11.
[50] Jackson R, Folaranmi SE, Goel N. Approach to the baby with bilious vomiting. Paediatr Child Health. 2021;32(1):1–6.
[51] Sevcik WE, Steiner IP. Acute gastric volvulus: case report and review of the literature. CJEM. 1999 Oct;1(3):200–3.
[52] Gourgiotis S, Vougas V, Germanos S, Baratsis S. Acute gastric volvulus: diagnosis and management over 10 years. Dig Surg. 2006;23(3):169–72.
[53] Cozart JC, Clouse RE. Gastric volvulus as a cause of intermittent dysphagia. Dig Dis Sci. 1998 May;43(5):1057–60.
[54] Tsang TK, Walker R, Yu DJ. Endoscopic reduction of gastric volvulus: the alpha-loop maneuver. Gastrointest Endosc. 1995 Sep;42(3):244–8.
[55] Garcia AM, Asad I, Tessaro MO, et al. A multi-institutional case series with review of point-of-care ultrasound to diagnose Malrotation and midgut volvulus in the Pediatric emergency department. Pediatr Emerg Care. 2019 Jun;35(6):443–7.
[56] Nguyen HN, Navarro OM, Bloom DA, et al. Ultrasound for midgut Malrotation and midgut volvulus: AJR Expert Panel narrative review. AJR Am J Roentgenol. 2022 Jun;218(6):931–9.
[57] Nguyen HN, Navarro OM, Guillerman RP, et al. Untwisting the complexity of midgut malrotation and volvulus ultrasound. Pediatr Radiol. 2021 Apr;51(4):658–68.
[58] Strouse PJ. Ultrasound for malrotation and volvulus: has the time come? Pediatr Radiol. 2021 Apr;51(4):503–5.
[59] Wong K, Van Tassel D, Lee J, et al. Making the diagnosis of midgut volvulus: limited abdominal ultrasound has changed our clinical practice. J Pediatr Surg. 2020 Dec;55 (12):2614–7.
[60] Binu V, Nicholson C, Cundy T, et al. Ultrasound imaging as the first line of investigation to diagnose intestinal malrotation in children: safety and efficacy. J Pediatr Surg. 2021 Dec;56(12):2224–8.
[61] Raske ME, Dempsey ME, Dillman JR, et al. ACR appropriateness criteria vomiting in infants up to 3 months of age. J Am Coll Radiol. 2015 Sep;12(9):915–22.
[62] Expert Panel on Pediatric Imaging; Alazraki AL, Rigsby CK, Iyer RS, et al.. ACR appropriateness criteria® vomiting in infants. J Am Coll Radiol. 2020 Nov;17(11S): S505–15.
[63] Zhang W, Sun H, Luo F. The efficiency of sonography in diagnosing volvulus in neonates with suspected intestinal malrotation. Med (Baltimore). 2017 Oct;96(42): e8287.
[64] Dufour D, Delaet MH, Dassonville M, et al. Midgut malrotation, the reliability of sonographic diagnosis. Pediatr Radiol. 1992;22(1):21–3.
[65] Zerin JM, DiPietro MA. Superior mesenteric vascular anatomy at US in patients with surgically proved malrotation of the midgut. Radiology. 1992 Jun;183(3):693–4.
[66] Strouse PJ. Disorders of intestinal rotation and fixation ("malrotation"). Pediatr Radiol. 2004;34:837–51.
[67] Pracros JP, Sann L, Genin G, et al. Ultrasound diagnosis of midgut volvulus: the "whirlpool" sign. Pediatr Radiol. 1992;22(1):18–20.
[68] Applegate KE. Evidence-based diagnosis of malrotation and volvulus. Pediatr Radiol. 2009;39(Suppl. 2):S161–3.
[69] Sizemore AW, Rabbani KZ, Ladd A, Applegate KE. Diagnostic performance of the upper gastrointestinal series in the evaluation of children with clinically suspected malrotation. Pediatr Radiol. 2008 May;38(5):518–28.
[70] Carroll AG, Kavanagh RG, Ni Leidhin C, et al. Comparative effectiveness of imaging modalities for the diagnosis of intestinal obstruction in neonates and infants:: a critically appraised topic. Acad Radiol. 2016 May;23(5):559–68.
[71] Long FR, Kramer SS, Markowitz RI, et al. Intestinal malrotation in children: tutorial on radiographic diagnosis in difficult cases. Radiology. 1996 Mar;198(3):775–80.
[72] Dilley AV, Pereira J, Shi EC, et al. The radiologist says malrotation: does the surgeon operate? Pediatr Surg Int. 2000;16(1–2):45–9.
[73] Berdon WE. The diagnosis of malrotation and volvulus in the older child and adult: a trap for radiologists. Pediatr Radiol. 1995;25(2):101–3.
[74] Kumbhar SS, Qi J. Fluoroscopic diagnosis of Malrotation: technique, challenges, and trouble shooting. Curr Probl Diagn Radiol. 2020;Nov-Dec;49(6):476-488.
[75] Morrison SC. Controversies in abdominal imaging. Pediatr Clin North Am. 1997 Jun; 44(3):555–74.
[76] Taylor GA. CT appearance of the duodenum and mesenteric vessels in children with normal and abnormal bowel rotation. Pediatr Radiol. 2011 Nov;41(11): 1378–83.

[77] Kouki S, Fares A, Alard S. MRI whirlpool sign in midgut volvulus with malrotation in pregnancy. JBR-BTR. 2013 Nov-Dec;96(6):360–1.
[78] Hsiao M, Langer JC. Value of laparoscopy in children with a suspected rotation abnormality on imaging. J Pediatr Surg. 2011 Jul;46(7):1347–52.
[79] Darani A, Mendoza-Sagaon M, Reinberg O. Gastric volvulus in children. J Pediatr Surg. 2005 May;40(5):855–8.
[80] Kotobi H, Auber F, Otta E, et al. Acute mesenteroaxial gastric volvulus and congenital diaphragmatic hernia. Pediatr Surg Int. 2005 Aug;21(8):674–6.
[81] Spector JM, Chappell J. Gastric volvulus associated with wandering spleen in a child. J Pediatr Surg. 2000 Apr;35(4):641–2.
[82] Chuang JH, Hsieh CS, Huang SC, et al. Gastric volvulus complicating left hepatic lobectomy. Pediatr Surg Int. 1993;8:255–6.
[83] Kayastha K, Sheikh A. Acute gastric volvulus secondary to malrotation of gut in a child with cerebral palsy. APSP J Case Rep. 2011 May;2(2):12.
[84] Marion Y, Rod J, Dupont-Lucas C, et al. Acute gastric volvulus: an unreported long-term complication of pericardial drainage. J Pediatr Surg. 2012 Dec;47(12):e5–7.
[85] Page MP, Kim HB, Fishman SJ. Small intestinal volvulus caused by loose surgical staples. J Pediatr Surg. 2009 Sep;44(9):1824–6.
[86] Pandey A, Singh SP, Gupta V, et al. Malrotation with midgut volvulus associated with perforated ileal duplication. J Indian Assoc Pediatr Surg. 2013 Oct;18(4):155–7.
[87] Park JJ, Wolff BG, Tollefson MK, et al. Meckel diverticulum: the Mayo Clinic experience with 1476 patients (1950-2002). Ann Surg. 2005 Mar;241(3):529–33.
[88] Alireza R, Mohammad SS, Mehrzad M, Houman A. Midgut volvulus caused by mesenteric lipoma. Iran J Pediatr. 2013 Feb;23(1):121–3.
[89] Kayastha K, Mirza B, Sheikh A. Volvulus of small bowel in a case of simple meconium ileus. APSP J Case Rep. 2011 Jan;2(1):7.
[90] Kosir MA, Sonnino RE, Gauderer MW. Pediatric abdominal lymphangiomas: a plea for early recognition. J Pediatr Surg. 1991 Nov;26(11):1309–13.
[91] McElreath DP, Olden KW, Aduli F. Hiccups: a subtle sign in the clinical diagnosis of gastric volvulus and a review of the literature. Dig Dis Sci. 2008 Nov;53(11):3033–6.
[92] Altonbary AY, Bahgat MH. Acute mesenteroaxial gastric volvulus: a rare cause of haematemesis. Arab J Gastroenterol. 2016 Mar;17(1):53–5.
[93] Applegate KE, Anderson JM, Klatte EC. Intestinal malrotation in children: a problem-solving approach to the upper gastrointestinal series. Radiographics. 2006 Sep-Oct;26(5):1485–500.
[94] Ballesteros Gómiz E, Torremadé Ayats A, Durán Feliubadaló C, et al. Intestinal malrotation–volvulus: imaging findings. Radiologia. 2015 Jan-Feb;57(1):9–21.
[95] Tackett JJ, Muise ED, Cowles RA. Malrotation: current strategies navigating the radiologic diagnosis of a surgical emergency. World J Radiol. 2014 Sep 28;6(9):730–6.
[96] Lampl B, Levin TL, Berdon WE, et al. Malrotation and midgut volvulus: a historical review and current controversies in diagnosis and management. Pediatr Radiol. 2009 Apr;39(4):359–66.
[97] Katz ME, Siegel MJ, Shackelford GD, McAlister WH. The position and mobility of the duodenum in children. AJR Am J Roentgenol. 1987 May;148(5):947–51.
[98] Hayden Jr CK, Boulden TF, Swischuk LE, Lobe TE. Sonographic demonstration of duodenal obstruction with midgut volvulus. AJR. 1984;143:9–10.
[99] Cohen HL. Ultrasound of the pediatric upper gastrointestinal tract. Bull N YAcad Med. 1989;65:583–90.
[100] Chao HC, Kong MS, Chen JY, Lin SJ, Lin JN. Sonographic features related to volvulus in neonatal intestinal malrotation. J Ultrasound Med. 2000;19:371–6.
[101] Orzech N, Navarro OM, Langer JC. Is ultrasonography a good screening test for intestinal malrotation? J Pediatr Surg. 2006 May;41(5):1005–9.
[102] Zhou LY, Li SR, Wang W, et al. Usefulness of sonography in evaluating children suspected of malrotation: comparison with an upper gastrointestinal contrast study. J Ultrasound Med. 2015;34:1825–32.
[103] Kumar B, Kumar M, Kumar P, Sinha AK, Anand U, Kumar A. Color Doppler: an effective tool for diagnosing midgut volvulus with malrotation. Indian J Gastroenterol. 2017;36:27–31.
[104] Karaman İ, Karaman A, Çınar HG, Ertürk A, Erdogan D, Zgüner IF. Is color Doppler a reliable method for the diagnosis of malrotation? J Med Ultrason. 2001;2018(45):59–64.
[105] Taghavi M, Alamdaran SA, Feizi A. Diagnostic value of ultrasound and gastrointestinal series findings in detection of pediatric intestinal malrotation. Iran J Radiol. 2018;15:e15089.
[106] Torres AM, Ziegler MM. Malrotation of the intestine. World J Surg. 1993;17:326–31.
[107] Seashore JH, Touloukian RJ. Midgut volvulus: an ever-present threat. Arch Pediatr Adolesc Med. 1994;148:43–6.
[108] Weinberger E, Winters WD, Liddell RM, et al. Sonographic diagnosis of intestinal malrotation in infants: importance of the relative positions of the superior mesenteric vein and artery. AJR. 1992;159:825–8.
[109] Ashley LM, Allen S, Teele RL. A normal sonogram does not exclude malrotation. Pediatr Radiol. 2001 May;31(5):354–6.
[110] Sodhi KS, Bhatia A, Saxena AK, et al. Anticlockwise swirl of mesenteric vessels: a normal CT appearance, retrospective analysis of 200 pediatric patients. Eur J Radiol. 2014 Apr;83(4):710–4.
[111] Yousefzadeh DK. The position of the duodenojejunal junction: the wrong horse to bet on in diagnosis or excluding malrotation. Pediatr Radiol. 2009;39:S172.
[112] Zafar M, Parvin J, Mcwhirter A, et al. Gastric volvulus: diagnosis and successful endoscopic De-rotation towards conservative Management in a Patient with Multiple Comorbidities. Cureus. 2022 Jul;14(7):e26862.
[113] Wolfgang R, Lee JG. Endoscopic treatment of acute gastric volvulus causing cardiac tamponade. J Clin Gastroenterol. 2001 Apr;32(4):336–9.
[114] Kodali VP, Maas LC. Endoscopic reduction of acute gastric volvulus. J Clin Gastroenterol. 1995 Dec;21(4):331–2.
[115] Lowenthal MN, Odes HS, Fritsch E. Endoscopic reduction of acute gastric volvulus complicating motor neuron disease. Isr J Med Sci. 1985 Jun;21(6):552–3.
[116] Ghosh S, Palmer KR. Double percutaneous endoscopic gastrostomy fixation: an effective treatment for recurrent gastric volvulus. Am J Gastroenterol. 1993 Aug;88(8):1271–2.
[117] Bhasin DK, Nagi B, Kochhar R, et al. Endoscopic management of chronic organoaxial volvulus of the stomach. Am J Gastroenterol. 1990 Nov;85(11):1486–8.
[118] Baudet JS, Armengol-Miró JR, Medina C, et al. Percutaneous endoscopic gastrostomy as a treatment for chronic gastric volvulus. Endoscopy. 1997 Feb;29(2):147–8.
[119] Kulkarni K, Nagler J. Emergency endoscopic reduction of a gastric volvulus. Endoscopy. 2007 Feb;39(Suppl. 1):E173.
[120] Chiarenza SF, Zolpi E, Costa L, et al. Pediatric gastric volvulus: is Laparoscopic Hill-snow-modified Gastropexy the effective Long-term minimally invasive solution? J Laparoendosc Adv Surg Tech A. 2022 Aug;32(8):913–9.
[121] Hani MB. A combined laparoscopic and endoscopic approach to acute gastric volvulus associated with traumatic diaphragmatic hernia. Surg Laparosc Endosc Percutan Tech. 2008 Apr;18(2):151–4.
[122] Koger KE, Stone JM. Laparoscopic reduction of acute gastric volvulus. Am Surg. 1993 May;59(5):325–8.
[123] Takahashi T, Yamoto M, Nomura A, et al. Single-incision laparoscopic gastropexy for mesentero-axial gastric volvulus. Surg Case Rep. 2019 Feb;5(1):19.
[124] Tamburini N, Andolfi C, Vigolo C, et al. The surgical Management of Acute Gastric Volvulus: clinical outcomes and quality of life assessment. J Laparoendosc Adv Surg Tech A. 2021 Mar;31(3):247–50.
[125] Messineo A, MacMillan JH, Palder SB, Filler RM. Clinical factors affecting mortality in children with malrotation of the intestine. J Pediatr Surg. 1992 Oct;27(10):1343–5.
[126] Andrassy RJ, Mahour GH. Malrotation of the midgut in infants and children: a 25-year review. Arch Surg. 1981 Feb;116(2):158–60.
[127] Yu DC, Thiagarajan RR, Laussen PC, et al. Outcomes after the Ladd procedure in patients with heterotaxy syndrome, congenital heart disease, and intestinal malrotation. J Pediatr Surg. 2009 Jun;44(6):1089–95. [discussion 1095].
[128] Catania VD, Lauriti G, Pierro A, Zani A. Open versus laparoscopic approach for intestinal malrotation in infants and children: a systematic review and meta-analysis. Pediatr Surg Int. 2016 Dec;32(12):1157–64.