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Imaging congenital anomalies of the ileum in adults: a pictorial review

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Abstract

The ileal loops are anatomical location for the majority of congenital anomalies affecting the gastrointestinal tract. These include Meckel's diverticulum, ileal duplication, dysgenesis, atresia, mucosal diaphragm, and malposition of the ileum. Symptomatic lesions that often present with abdominal pain, intestinal obstruction or bleeding are usually diagnosed and treated during infancy and childhood. However, many of these congenital conditions may remain clinically silent and detected incidentally in adults undergoing radiological evaluation for unrelated medical reasons. This article presents the spectrum of the congenital ileal anomalies and their distinct features on small bowel examination and CT of the abdomen.

Keywords Congenital intestinal anomalies · Meckel's diverticulum · Ileal duplication · Ileal dysgenesis · Atresia and malposition · Radiographic and CT features

Introduction

The small intestine of human adult measures 20–30 feet in length at autopsy, but it is somewhat shorter in the living body due to constant smooth muscle tone and peristaltic contractions [1, 2]. The distal half of small bowel forms the ileal loops which are involved in the final resorption of nutrients, bile acids and vitamin B12. The ileum is also a unique location where most of congenital gastrointestinal anomalies occur and present with distinct radiological features [3, 4]. Some of them like Meckel's diverticulum have an embryological etiology related to incomplete obliteration of omphalomesenteric duct in developing fetus. Others have either idiopathic nature or caused by mesenteric vascular ischemia during the fetal life, as postulated in cases of ileal atresia, duplication, and dysgenesis [3–7]. While many of these lesions involve the middle part of ileal loops, the most distal segment or terminal ileum that harbors submucosal lymphoid follicles in Peyer's patches is the predominant site of inflammatory conditions (Crohn's disease, tuberculosis) or neoplastic processes (lymphoma, carcinoid) [8].

Most congenital lesions of the ileum are diagnosed and treated in newborn infants and children. However, delayed clinical manifestation and radiological detection of these lesions in adults are also common occurrence [3, 4, 7]. The purpose of this article is to present the imaging features of various congenital anomalies of the ileum that are first recognized in adulthood, and to review the literature about their pathogenesis and clinical implications.

Meckel's Diverticulum

Meckel's diverticulum is the most common congenital anomaly of the ileum and occurs in 2–3% of general population. It is the vestigial remnant of vitelline or omphalomesenteric duct, which connects the yolk sac to the midgut and normally obliterates during the 7th or 8th weeks of gestation. However, the proximal part of its attachment may persist as a saccular outpouching on the antimesenteric border of the ileum [3, 5].

The diverticular wall is composed of all three layers of intestine, but often harbors islands of heterotopic gastric epithelium or pancreatic tissue. Their glandular secretions can cause peptic ulceration, hemorrhage, cicatricial stenosis, inflammation, and perforation [3, 9, 10].

The often-quoted description of Meckel's diverticulum by the rule of 2's refers to its 2% incidence among the population, 2 feet distance from the ileocecal valve, most being 2

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inches long, 2% symptomatic usually by age of 2 years, 2:1 male to female ratio, and harboring 2 types of heterotopic mucosa in 1 of 2 cases [3, 4, 10]. It should be noted that this rule applies primarily to the pediatric age group. Adults have much longer small bowel than children and their Meckel's diverticulum can be 3–4 feet proximal to the ileocecal valve, and much larger in size to over 4 inches (10 cm) in diameter to be called giant Meckel's diverticulum [11–13]. They contain heterotopic gastric mucosa in 40–60% and pancreatic or other tissues in up to 10% of cases. This may account for the variety of primary neoplasms that can originate within a Meckel's diverticulum in 3.2% of cases. These include carcinoid as the most common diverticular malignancy in 33%–44% of reported cases, followed by leiomyosarcoma in 18%–25%, adenocarcinoma in 12%–16% and gastrointestinal stromal tumor [14, 15]. Nevertheless, most Meckel's diverticula in adults are asymptomatic and incidental finding at surgery or imaging studies performed for unrelated conditions [3, 4, 10].

A Meckel's diverticulum can be suspected on abdominal radiograph by the presence of a persistent gas collection within a saccular structure in the right lower abdomen, particularly if it also contains enteroliths or foreign

bodies. A more reliable method of diagnosis is the actual opacification of it by small bowel examination or reflux into the ileum during barium enema study (Fig. 1a, b). About 80% of 118 Meckel's diverticula in adults reported by Clark and associates had been detected by radiography or scintigraphy, and 20% by CT [3].

In the past four decades CT has become the principal modality for demonstrating Meckel's diverticulum. The lesion can be visualized on CT examinations of the abdomen that are performed with or without oral contrast administration. The typical finding is a round or ovoid saccular structure containing gas or fluid and attached to the antimesenteric wall of the ileum (Fig. 2a–c). On imaging studies, therefore, the Meckel's diverticula will always face away from the center of the abdomen where the root of mesentery runs obliquely from duodenojejunal flexure to the ileocecal region [3, 9, 10, 16].

There have been isolated reports about the diagnosis of Meckel's diverticulum by ultrasonography or MRI [3, 10, 17]. About 50% of symptomatic Meckel's diverticula harbor heterotopic gastric mucosa, which can be detected by Tc-99 m pertechnetate scintigraphy. However, the radionuclide Meckel's scan can also be positive if ileal duplication cyst or dysgenesis contain heterotopic gastric tissue [18].

Fig. 1 Radiographic appearance of Meckel's diverticulum in 2 adult patients. **a** Small bowel examination shows a barium-filled 4×6 cm diverticulum attached to the ileum (arrows). **b** Barium enema with retrograde flow into the ileum demonstrates a Meckel's diverticulum as a 3 cm saccular outpouching from the antimesenteric wall of distal ileum (arrows)

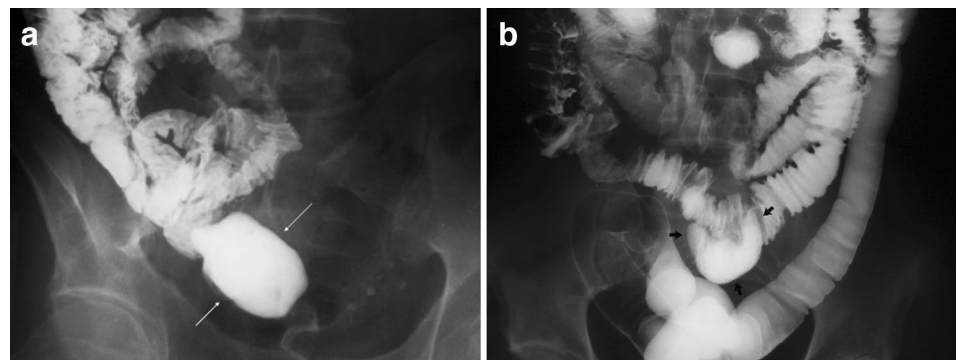


Fig. 2 CT images of Meckel's diverticulum in 3 patients. **a** Presenting as a fluid-filled pocket attached to the distal ileum (arrow). **b** Containing enteroliths within its lumen (arrow). **c** Opacified with oral contrast on CT image of the pelvic region (arrow)

Ileal duplication

Gastrointestinal duplication is a rare congenital anomaly that occurs in about one of every 10,000 newborn infants. It can be located in any part of the alimentary tract, but the distal ileum is the most common site of it. The underlying pathogenesis is proposed to be the persistence of embryonic gut diverticula or defective recanalization of the primitive gut lumen [4, 19, 20].

Ileal duplications are characterized by their typical location on the mesenteric side of the intestinal wall and composed of the same muscular and mucosal layers of adjoining segment. However, about a third of the resected ileal duplications also contain gastric epithelium or other heterotopic tissues [4, 19, 21].

Most ileal duplication present before the age of 2 years as an acute abdomen or bowel obstruction, but the rest may remain asymptomatic until adulthood and diagnosed as an incidental finding during laparotomy or imaging studies [22, 23]. About 80% of ileal duplication have a cystic configuration and contain clear fluid from mucosal secretion. Others have a tubular shape and often communicate with the

lumen of attached intestine. These are visualized on small bowel examination as a blind-ending tubular outpouching on the mesenteric aspect of distal ileum (Fig. 3a). They can be very large and attached as an elongated structure in the ileal wall. Matsumoto et al. recently reported a 60-year-old man in whom the ileal duplication appeared on CT and resected specimen as a tortuous tubular lesion measuring 18 cm long and 7 cm in diameter [24].

There have been isolated case reports of coexisting ileal duplication and Meckel's diverticulum [18, 19]. They can be located separately or involve the opposite walls of the same segment (Fig. 3b). A communicating tubular duplication can mimic the Meckel's diverticulum because of their similar radiographic and pathologic features. Therefore, their differentiation depends upon anatomical relation to the intestinal mesentery [25, 26].

Several authors have presented the appearance of ileal duplication on CT or MRI of patients with abdominal pain and distention [23, 24]. A cystic ileal duplication with ectopic gastric mucosa causing inflammation or ulceration can be seen as a mass with enhancing walls on CT of the abdomen (Fig. 4).

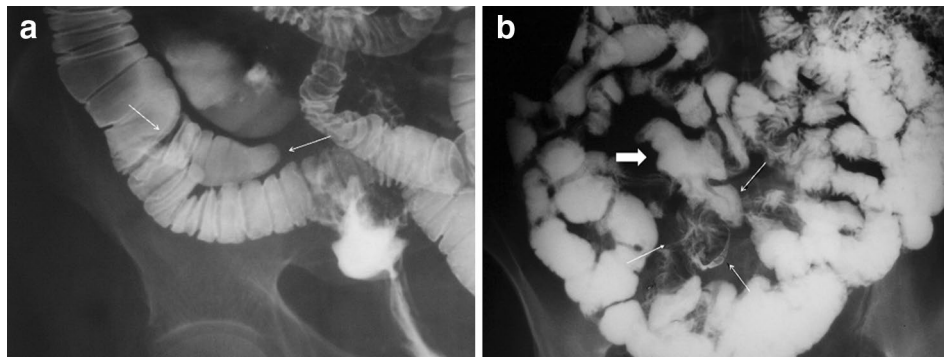
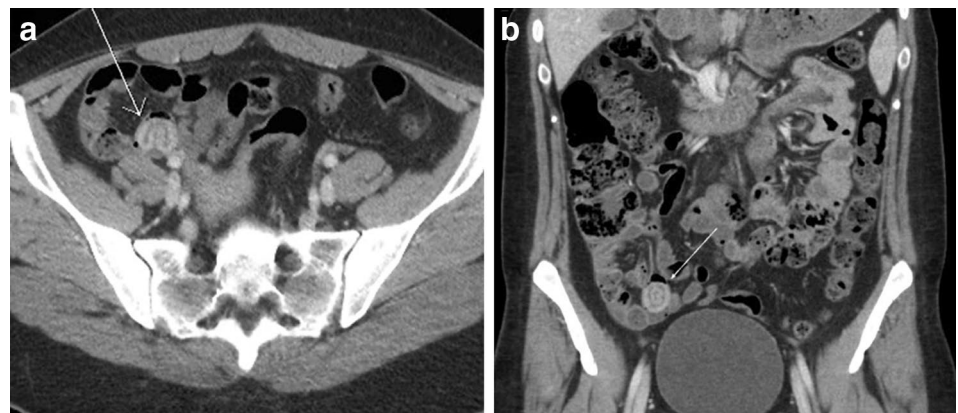


Fig. 3 Radiographs of ileal duplications in 2 different patients. **a** Image from an enteroclysis study reveals a blind-ending tubular duplication connected to the mesenteric side of distal ileum (arrows). **b** Small bowel series in this woman showed a large saccular lesion

in mid-ileum. The pathological evaluation of resected segment confirmed that the lobulated part was a Meckel's diverticulum (small arrows), but the finger-like outpouching on the mesenteric side was a duplication (large arrow)

Fig. 4 CT appearance of a cystic ileal duplication. **a, b** Axial and coronal sections of the abdomen demonstrate a round soft tissue mass with enhancing walls in the mesenteric border of distal ileum (arrow).



It has been advocated that even an incidentally diagnosed ileal duplication should also be resected to prevent potential complications such as perforation, enteric bleeding, and bowel obstruction due to volvulus or intussusception [19–21]. Furthermore, there have been rare instances of malignant transformation and development of adenocarcinoma or gastrointestinal stromal tumor within ileal duplications [27, 28].

Dysgenesis of the ileum

Ileal dysgenesis or aneurysmal dilatation is a rare congenital anomaly, and about 50 cases have been reported in children and adults [7, 29]. It usually involves a 5–25 cm segment that can be dilated up to 10–15 cm wide along the long axis of the ileum. The underlying cause of it is the localized absence or dysfunction of the myenteric plexus which provides motor innervation to the muscular layers of the gut. Therefore, the affected segment cannot contract and becomes passively distended due to stasis of intestinal content. This aperistaltic part of the ileum will also act as a barrier to the propagation of peristalsis, causing distention of the proximal loops of small bowel. Therefore, these patients will usually present

with intermittent obstructive symptoms and undergo radiological studies to reveal the cause of it [7, 29–31].

The typical abnormality seen on small bowel examination is a dilated segment of the ileum that is well-demarcated and in direct continuity with the lumen (Fig. 5a, b). Similar findings on barium studies had been reported in 3 patients by Usselman et al. [31], and in a series of 9 cases by Javors and associates [7]. There have been only few documented cases on CT or MRI [30], but the distinct appearance of the lesion on abdominal CT provides an important clue to the diagnosis (Fig. 6).

Ileal dysgenesis may occur in coexistence with Meckel's diverticulum or duplication cyst [30]. It may also contain heterotopic gastric mucosa causing peptic ulceration and bleeding. These features as well as the occurrence in children support the concept about the congenital nature of this anomaly and its possible relation to the omphalomesenteric obliteration during embryological development [7, 29–31].

This condition should be distinguished from aneurysmal dilatation of the ileum due to lymphoma or pre-stenotic dilatation in Crohn's disease, which are usually associated with marked thickening of the intestinal wall in contrast to its normal appearance in the ileal dysgenesis [7, 31–33].

Fig. 5 Radiographic appearance of ileal dysgenesis in 2 patients.

a An image obtained during enteroclysis shows aneurysmal dilatation of a proximal ileal segment (arrows). **b** Small bowel examination demonstrates a well-demarcated 8 cm long part of the ileum that is dilated to 5 cm in diameter (arrow)

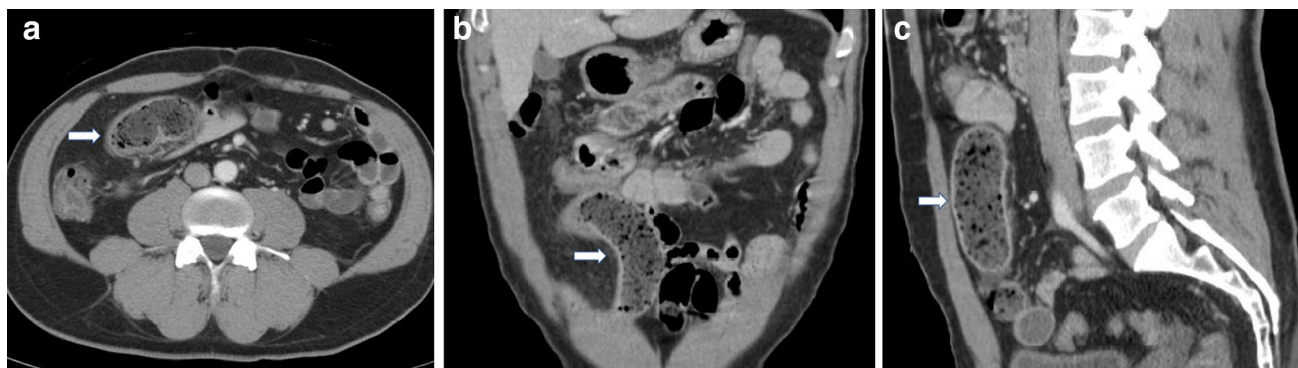
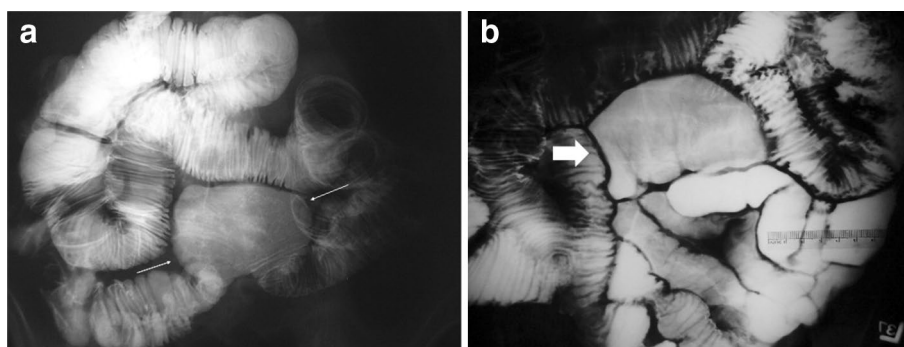


Fig. 6 CT of the abdomen in a man with ileal dysgenesis. **a–c** Axial, coronal and sagittal images reveal a dilated 12 cm long segment of distal ileum with stasis of intestinal content in its lumen (arrow)

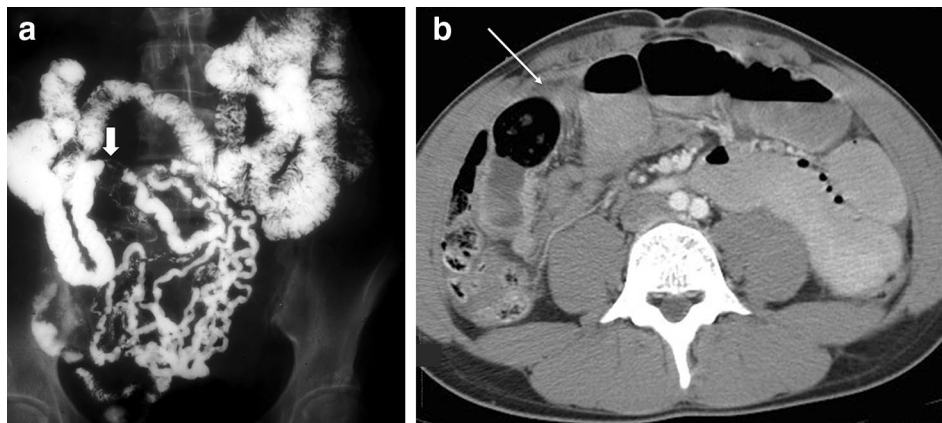


Fig. 7 Congenital stenosis and mucosal diaphragm in 2 cases. **a** Small bowel examination of this young woman disclosed a markedly reduced caliber of the ileal loops. This micro-ileum was delayed consequence of a short proximal stenosis (arrow), which had interfered with the flow of intestinal content and normal development of the

ileum. **b** CT of the abdomen in this man showed small bowel obstruction due to a mucosal diaphragm in distal ileum (arrow). Laparotomy revealed that the diaphragm's orifice had been blocked by an ingested bag of Heroin

Another differential diagnostic consideration would be an entity called segmental absence of the intestinal musculature (SAIM) [34–36]. This condition involves partial or complete absence of muscularis propria, causing marked thinning of the bowel wall. It is manifested by intestinal obstruction or perforation in neonates and children, but also occasionally in adults. It has been postulated that SAIM may result from dysplasia of intestinal muscle layer in embryo or transient bowel ischemia in premature infants. Some authors suspect that the frequent proximity of the affected segment to the site of Meckel's diverticula would indicate that this malformation may be caused by localized resorption of ileal muscle during regression of the omphalomesenteric duct [34–36].

Ileal atresia, stenosis, and intraluminal diaphragm

Intestinal atresia occurs in 1 of every 5–14 thousand live births and the ileum is the site of it in 30% of cases [6, 37]. The underlying pathogenesis is mesenteric vascular ischemia in utero, whereas the esophageal and duodenal atresia is due to failed recanalization of the primitive foregut [38, 39].

In total atresia the blind-ending ileum will lead to marked distention of the proximal intestinal loops that can be recognized on prenatal sonography [40]. Abdominal radiographs obtained after birth reveal small bowel obstruction or perforation, prompting surgical treatment. In partial ileal atresia classified as type 1, there is only narrowing of the lumen due to focal stenosis or a mucosal diaphragm with open foramen. Therefore, the clinical and radiological manifestations of bowel obstruction will be less pronounced, and the diagnosis may be delayed until adulthood [37–39, 41].

When an stenotic segment is in the jejunum or proximal ileum, it would slow the passage of intestinal content and interfere with natural growth and development of the ileal loops. This can result in their diminished caliber over a prolonged time and the appearance of micro-ileum on small bowel examination (Fig. 7a). This condition is rarely encountered in adults who may develop an atrophic micro-ileum after a proximal ileostomy but is very similar to microcolon seen in infants with intestinal atresia or meconium plug syndrome [42, 43].

Another manifestation of a partial ileal atresia is the occurrence of intraluminal mucosal diaphragm with central aperture [41, 44]. This lesion closely resembles the radiographic and pathologic appearance of mucosal diaphragms found in the gastric antrum or duodenum [45, 46]. If the orifice of an ileal diaphragm is larger than 1 cm in diameter, it may not hinder the passage of intestinal content. However, blockage of this foramen by undigested food particles, raw vegetables or ingested foreign objects can cause an acute onset of small bowel obstruction (Fig. 7b).

The congenital diaphragm of the ileum has been encountered in both children and adults [41, 44, 47] Wang and associates have reported 5 patients with ileal diaphragms, whose mean age was 41.6 years at the time of diagnosis, and they had experienced intermittent intestinal symptoms for 2–16 years. Their ileal diaphragms were demonstrated by CT enterography and enteroscopy prior to surgical resection [47]. This anomaly should be differentiated from acquired lesions in intestinal membrane disease, whereby intraluminal mucosal diaphragms are caused by long-term use of nonsteroidal anti-inflammatory drugs [48, 49].

Fig. 8 Congenital malposition of the ileum in left paraduodenal hernia. **a** Post evacuation radiograph of barium enema study shows the distal ileum extending across the abdomen (white arrows) and other ileal loops are encapsulated within the fossa of Landzert (Black arrow). **b** Coronal CT image of another patient shows the entrapped ileal loops in the left upper abdomen (arrows)

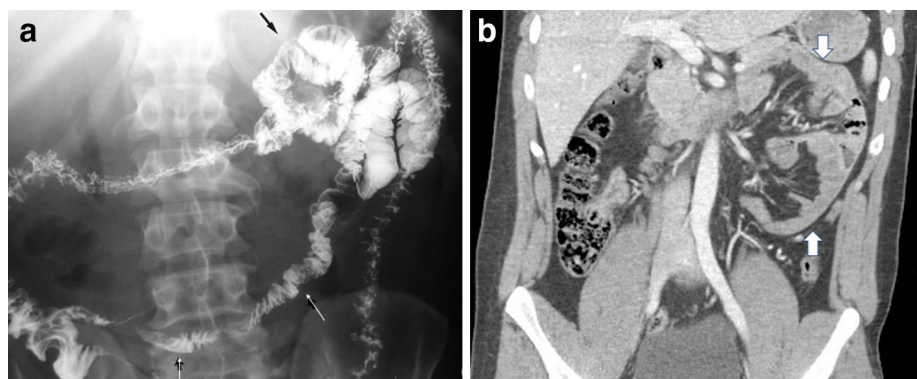


Fig. 9 Barium enema examination of this patient reveals congenital malposition of an ileal loop in the right paracolic and subphrenic spaces along with medially displaced hepatic flexure

Congenital malposition of the ileum

The ileal loops are normally located in the right lower abdomen, but anomalies of the intestinal rotation and fixation can cause malposition of the ileum in other compartments of abdominal cavity [50, 51].

In cases of intestinal malrotation, the small bowel occupies the right side of the abdomen, whereas the distal ileum and colon will be on the left side. In patients with left

paraduodenal hernia, the ileal loops may be encapsulated within the fossa of Landzert, a peritoneal pocket in the left upper abdomen (Fig. 8a, b). The left paraduodenal hernia is the most common site of internal herniation and accounts for 53% of these congenital conditions [51].

There are occasional instances, whereby the ileal loops are malpositioned in the right upper abdomen due to congenital herniation into the right paracolic fossa (Fig. 9). In a case reported by Aggarwal et al. [52], the ileal loops with an attached Meckel's diverticulum were found in a right paracolic hernia on CT examination.

Conclusion

Most congenital anomalies of the gastrointestinal occur in the ileum and can be demonstrated on barium examination of the small bowel or CT of the abdomen.

The differences in anatomical location, appearance, and underlying pathogenesis of various congenital ileal anomalies are summarized in Table 1.

These lesions usually present with abdominal pain, bowel obstruction, or intestinal hemorrhage during infancy and childhood. However, a significant number of them are either asymptomatic or have delayed clinical presentation and diagnosis until adulthood. It is important for the practicing radiologists to be familiar with the spectrum of imaging features of these ileal anomalies, their pathogenesis, and potential complications.

Table 1 Differential features of congenital anomalies of the ileum

Anomalous lesion	Location & appearance	Pathogenesis
Meckel's diverticulum	Antimesenteric border, saccular	Vitelline duct remnant
Duplication cyst	Mesenteric border, cystic or tubular	Embryonic gut division
Ileal dysgenesis	Aneurysmal dilatation of lumen	Neuromuscular defect
Ileal atresia	Obstructed blind-ending segment	Fetal intestinal ischemia
Mucosal diaphragm	Protruding Intraluminal web	Re-canalization failure
Ileal malposition	Atypical site in peritoneal cavity	Midgut rotation/fixation

Declarations

Conflict of interest The author declares no conflict of interest and has no disclosure relevant to the subject matter of this article.

Ethical approval Due to the retrospective review of the already performed and medically warranted examinations, the patients consent, and IRB approval were waived.

References

- Hounnou G, Destrieux C, Desme J, et al (2002) Anatomical study of the length of the human intestine. *Surg Radiol Anat* 24: 290–294.
- Raines D, Arbour A, Thompson HW, et al (2015) Variation in small bowel length: factor in achieving toral enteroscopy? *Dig Endosc* 27: 67–72.
- Clark JK, Paz DA, Ghahremani GG (2014) Imaging of Meckel's diverticulum in adults: pictorial essay. *Clin Imaging* 38: 557–564.
- Vaos G, Misiakos EP (2010) Congenital anomalies of the gastrointestinal tract diagnosed in adulthood- diagnosis and management. *J Gastrointest Surg* 14: 916–925.
- Inarejos Clemente EJ, Navarro OM, Irujo MN, et al (2021) Omphalomesenteric duct anomalies in children: a multimodality overview. *RadioGraphics* 41: 2090–2110.
- Subbarayan D, Singh M, Khurana N, Sathish A (2015) Histomorphological features of intestinal atresia and its clinical correlation. *J Clin Diagn Res* 9 (11): EC26–29.
- Javors BR, Gold RP, Ghahremani GG, et al (1995) Idiopathic. Localized dilatation of the ileum in adults: findings on barium studies. *AJR* 164: 87–90.
- Jung C, Hugot JP, Barreau F (2010) Peyer's patches: the immune sensors of the intestine. *Int J Inflam* 2010:823710.
- Platon A, Gervaz P, Becker CD, et al (2010) Computed tomography of complicated Meckel's diverticulum in adults: a pictorial review. *Insights Imaging* 1: 53–61.
- Elsayes KM, Menias CO, Harvin HJ, Francis IR (2007) Imaging manifestations of Meckel's diverticulum. *AJR* 189: 81–88.
- Ren B, Jia X, Li L (2015) Intestinal obstruction due to axial torsion of a giant Meckel's diverticulum: a case report. *Int J Colorectal Dis* 30: 1133–1134.
- Luu AM, Meurer K, Herzog T et al (2016) Small bowel obstruction due to a giant Meckel's diverticulum. *Visc Med* 32: 434–436.
- Akbulut S, Yagmur Y (2014) Giant Meckel's diverticulum: an exceptional cause of intestinal obstruction. *World J Gastrointest Surg* 6: 47–50.
- Van Malderen K, Vijayvargiya P, Camilleri M, et al (2018) Malignancy and Meckel's diverticulum: a systematic literature review and 14-year experience at a tertiary referral center. *United Euro Gastroenterol* 6:739–747.
- Kabir SA, Raza SA, Kabir SI (2019) Malignant neoplasms of Meckel's diverticulum; an evidence-based review. *Ann Med Surg* 43: 75–81.
- Okino Y, Kiyosue H, Mori H, et al (2001) Root of the small-bowel mesentery: correlative anatomy and CT features of pathologic conditions. *RadioGraphics* 21: 1475–1490.
- Baldisserotto M, Meffazzoni DR, Dora MD (2003) Sonographic findings of Meckel's diverticulitis in children. *AJR* 180: 425–428.
- Yang JG, Yin CH, Li CL, Zou LF (2010) Meckel's diverticulum and intestinal duplication detected by Tc-99m pertechnetate scintigraphy. *Clin Nucl Med* 35: 275–276.
- Nebot CS, Salvador RL, Palacios EC, et al (2018) Enteric duplication cyst in children: varied presentations, varied imaging findings. *Insight Imaging* 9: 1097–1106.
- Puligandla PS, Nguyen LT, St-Vil D, et al (2003) Gastrointestinal duplications. *J Pediatr Surg* 38: 740–744.
- Gandhi D, Garg T, Shah J, et al (2022) Gastrointestinal duplication cysts: what a radiologist needs to know. *Abdom Radiol* 47: 13–27.
- Fiorani C, Scaramuzza R, Lazzaro A, et al (2011) Intestinal duplication in adulthood: a rare entity, difficult to diagnose. *World J Gastrointest Surg* 3: 128–130.
- Lee NK, Kim S, Jeon TY, et al (2010) Complications of congenital and developmental anomalies of the gastrointestinal tract in adolescents and adults: evaluation with multimodality imaging. *RadioGraphics* 30: 1489–1507.
- Matsumoto Y, Tohma T, Miyauchi H, et al (2015) A case of giant ileal duplication in an adult, successfully treated with laparoscope-assisted surgery. *Surg Case Rep* 1: 10.
- Alenizi EK, Alfeeli MA (2008) Intestinal duplication mimicking Meckel's diverticulum. *Clin Nucl Med* 33: 189–190.
- Hamza A, Bicaj BX, Kurshumliu F, et al. (2016) Mesenteric Meckel's diverticulum or intestinal duplication cyst: a case report with review of literature. *Internat J Surg Case Rep* 26: 50–52.
- Habib K, Khan M, Sheehan AL, Coker O (2009) Adenocarcinoma in ileal duplication cyst: case report and review of literature. *Cent Eur J Med* 4: 374–378.
- Furuya K, Hada M, Sugai H, et al (2012) Gastrointestinal stromal tumor arising in an ileal duplication: report of a case. *Surgery Today* 42: 1234–1239.
- Oberhelman AP, Herman TE, McAlister WH, et al (2007) CT manifestations of ileal dysgenesis. *Pediatr Radiol* 37: 209–212.
- Dillman JR, Neef HC, Ehrlich PF, et al (2012) Ileal dysgenesis coexisting with multiple enteric duplication cysts in a child: MR enterography, CT, and Meckel scan appearances. *Pediatr Radiol* 42: 1517–1522.
- Usselman JA, Ghahremani GG, Bordin GM, et al (1981) Idiopathic localized dilatation of the ileum in adults. *Gastrointest Radiol* 6: 313–317.
- Maizlin ZV, Brown JA, Buckley MRE, et al (2006) Case of the season: aneurysmal dilatation of the small bowel (not only lymphoma) *Semin Roentgenol* 41: 248–249.
- Jasti R, Carucci LR (2020) Small bowel neoplasms: a pictorial review. *RadioGraphics* 40: 1020–1038.
- Davis JS, Ryan ML, Shields JM, et al (2012) Segmental absence of intestinal musculature: an increasingly reported pathology. *J Pediatr Surg* 47: 1566–1571.
- Nawar NA, Sawyer PR (2016) Segmental absence of intestinal musculature in a 64-year-old female: case report and literature review. *Am J Case Rep* 17: 749–754.
- Tamai M, Satoh M, Tsujimoto A (2013) Segmental muscular defects of the intestine: a possible cause of spontaneous perforation of the bowel in adults. *Hum Pathol* 44:m 2643–2650.
- Burjonrappa S, Crete E, Bouchard S (2011) Comparative outcomes in intestinal atresia: a clinical outcome and pathophysiology analysis. *Pediatr Surg Int* 27: 437–442.
- Aggerwal N, Sugandhi N, Kour H, et al (2019) Total intestinal atresia: revisiting the pathogenesis of congenital atresias. *J Indian Assoc Pediatr Surg* 24: 303–306.
- Stollman TH, deBlaauw I, Wijnen MH (2009) Decreased mortality but increased morbidity in neonates with jejunoileal atresia: a study of 114 cases over a 34-year period. *J Pediatr Surg* 44: 217–221.
- Virgone C, D'antonio F, Khalil A, et al (2015) Accuracy of prenatal ultrasound in detecting jejunal and ileal atresia: systematic review and meta-analysis. *Ultrasound Obstet Gynecol* 45: 523–529.

41. Levesque HP, Ciricillo DR, Sylvestre J, et al (1983) Mucosal diaphragm and enteroliths of the small bowel causing obstruction in an adult. *Am J Gastroenterol* 78: 593-595.
42. Munden RF, Schabel SI (1993) Acquired microileum: a companion to microcolon? *J Clin Gastroenterol* 16: 344-345.
43. Lo WC, Wang CR, Lim KE (1998) Microcolon in neonates: clinical and radiographic appearance. *Clin Neonatol* 5: 14-18.
44. Agha FP, Jenkins JJ (1983) Ileal mucosal diaphragm causing small bowel obstruction. *Gastrointest Radiol* 8: 57-59.
45. Pederson WC, Sirinek KR, Schwesinger WH, Levine BA (1984) Gastric outlet obstruction secondary to antral mucosal diaphragm. *Digest Dis Sci* 29: 86-90.
46. Lin HH, Lee HC, Yeung CY, et al (2012) Congenital webs of the gastrointestinal tract: 20 years of experience from a pediatric care teaching hospital in Taiwan. *Pediatr Neonatol* 53: 12-17.
47. Wang ML, Mia F, Tang YH, et al (2011) Special diaphragm-like strictures of small bowel unrelated to non-steroidal anti-inflammatory drugs. *World J Gastroenterol* 17: 3596-3604.
48. Velchuru VR, Rimal D, Studley JGN, Sturzaker HG (2006) Diaphragm disease of the ileum. *Int J Surg* 4: 184-186.
49. Flicek KT, Hara AK, Petris GD, et al (2014) Diaphragm disease of the small bowel: a retrospective review of CT findings. *AJR* 202: W140-145.
50. Pickhardt PJ, Bhalla S (2002) Intestinal malrotation in adolescents and adults: spectrum of clinical and imaging features. *AJR* 179: 1429-1435.
51. Ghahremani GG (2000) Abdominal and pelvic hernias. In Gore RM and Levine MS: *Textbook of Gastrointestinal Radiology*. 2nd Edition, WB Saunders, Philadelphia, pages 1993-2009.
52. Aggarwal BK, Rajan S, Aggarwal A, et al (2004) CT diagnosis of Meckel diverticulum in a paracolic internal hernia. *Abdom Imaging* 30: 56-59.

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