

Many faces of Meckel's diverticulum and its complications

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Received: 28 December 2015 / Accepted: 12 February 2016 / Published online: 1 March 2016
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Abstract Meckel's diverticulum is the most common congenital abnormality of the gastrointestinal tract. It is a true diverticulum containing all layers of the intestinal wall and identified as a saccular, blind-ending structure located on the antimesenteric border of the distal ileum. Most patients remain asymptomatic during their lifetime. Symptomatic cases are nonspecific and can present as small-bowel obstruction, diverticulitis, perforation, gastrointestinal bleeding, and rarely, a neoplasm. Therefore, the radiological diagnosis is of paramount importance for proper patient management.

Keywords Meckel's diverticulum · Complication · Imaging · Meckel's diverticulitis

Introduction

Meckel's diverticulum is the most common congenital abnormality of the gastrointestinal (GI) tract. In the majority of patients, it is asymptomatic and usually found within 40–100 cm of the ileocecal valve. In symptomatic cases,

clinical presentation is unspecific and mimics many other conditions, such as appendicitis and small-bowel obstruction. The purposes of this review are to describe embryology and anatomy, describe the value and limitations of different imaging modalities in diagnosis, and emphasize the important complications.

Teaching points:

- Meckel's diverticulum is the most common congenital abnormality of the gastrointestinal tract
- Meckel's diverticulum is a true diverticulum
- The most common heterotopic tissue within Meckel's diverticulum is gastric mucosa
- Junctional fold patterns on barium examination confirm the presence of Meckel's diverticulum
- Computed tomography is the imaging modality of choice in the diagnosis of complicated Meckel's diverticulum
- Gastrointestinal bleeding is the most common complication of Meckel's diverticulum
- Carcinoid tumor is the most commonly reported neoplasm complicating Meckel's diverticulum

Embryology and anatomy

Meckel's diverticulum, the remnant of the omphalomesenteric or vitelline duct that connects the fetal midgut to the yolk sac, is reported to occur in 2 % of the population [1]. In the embryonic period, the midgut temporarily communicates with the yolk sac through the omphalomesenteric duct, which is typically regressed during the fifth to eighth week of life. Failed or incomplete closure of the duct results in two main variants: one resulting from complete regression of the fibrous channel to the umbilicus, resulting

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a diverticulum with a free blind end (Meckel's diverticulum; 90 % of cases), and the other occurring in the form of a persistent fibrous band connecting the diverticulum to the umbilicus. Other less common variants are umbilicoileal fistula, umbilical sinus, umbilical cyst, and a fibrous cord connecting the ileum to the umbilicus.

Meckel's diverticulum identified as a saccular, blind-ending structure usually found at the antimesenteric border of the distal small bowel, typically 40–100 cm from the ileocecal valve; Yamakuchi et al. reported an average distance of 50 cm [2]. It is a true diverticulum comprising mucosa, muscularis, and serosa. It is typically lined with ileal mucosa-type epithelium but, occasionally, heterotopic tissue is found. The gastric mucosa is the most common tissue (62 % of cases) [2], but others include pancreatic tissue (6 %), combined gastric mucosa and pancreatic tissue (5 %), jejunal mucosa (2 %), Brunner's glands (2 %), and other tissues (10 %) [2]. Its finger-like structure is 3–5 cm long, with an axial diameter up to 2 cm, but it occasionally presents as a large, saccular lesion up to 5–10 cm diameter [3]. Rare cases of diverticula larger than the ileal loops have been reported [4, 5].

Vascular supply is via the omphalomesenteric artery, which is the origin of two vitelline arteries. One artery disappears during the fifth to sixth week of gestation, while the other becomes the superior mesenteric artery (SMA). Arterial supply of the persistent omphalomesenteric duct is fed by a remnant of the primitive vitelline artery arising from the ileal branch of the SMA or, less frequently, from the ileocolic artery.

Classic description

The “rule of twos” is the classic description for Meckel's diverticulum: It is present in 2 % of the population, with a 2:1 male to female ratio, is found approximately 2 feet from the ileocecal valve, measures 2 inches in length, is frequently symptomatic before 2 years of age, and 2 % of these patients develop complications over their lifetime [1]. Large diverticula >2 cm have a high risk of complication than shorter diverticula.

Clinical presentations

Most Meckel's diverticulum is clinically silent and incidentally discovered during radiologic examination or abdominal surgery for unrelated conditions [6]. It has no association with other major congenital malformations. Intestinal bleeding is the most common complication in the pediatric population, usually associated with diverticula containing ectopic gastric mucosa [7]. Intestinal obstruction is

the second most common complication. However, clinical symptoms from complications occur more frequently in the adult population [1] and include small-bowel obstruction and diverticulitis with or without complications such as perforation, GI bleeding, and neoplasm.

Imaging diagnosis of Meckel's diverticulum

Various imaging modalities have been used to diagnose Meckel's diverticulum. However, computed tomography (CT) with the adjunct of scintigraphy or angiography are frequently used, particularly when there is a complication.

Plain film

Plain film is generally considered of limited value, although it can show enteroliths, calcific contents, gas-filled diverticulum (Fig. 1), or complication such as bowel obstruction or pneumoperitoneum—the latter if perforation has occurred.

Barium examination

Meckel's diverticulum is sometimes difficult to detect or distinguish from normal small bowel because of its small orifice, peristalsis with prompt emptying, or blockage of barium filling by internal contents. When there is a complication, barium examination should be avoided due to the risk of barium leakage. Other limitations include overlapping of small-bowel loops and incomplete small-bowel distension. Key features of barium examination are identification of junctional fold patterns (Fig. 2), especially at the site of attachment to the normal small bowel, which includes a “triradiate fold pattern” when the loops are collapsed (Fig. 3) and a “mucosal triangular plateau” when the loops are distended. Both are termed “junctional fold pattern” and are considered as characteristic [8]. Filling defects and mucosal irregularity in the diverticula may suggest intussusception and gastric mucosa or tumor.

Sonography

Sonography, although of limited value, merits discussion, since it is widely available in all institutions. The characteristic sonographic pattern of Meckel's diverticulum is “the gut signature”, formed by an alternate hyperechoic inner layer corresponding to mucosa/submucosa, and hypoechoic outer layer corresponding to the muscular layer. In cases of obstructed or fluid-filled diverticulum, sonography may show a variable pattern (Fig. 4).

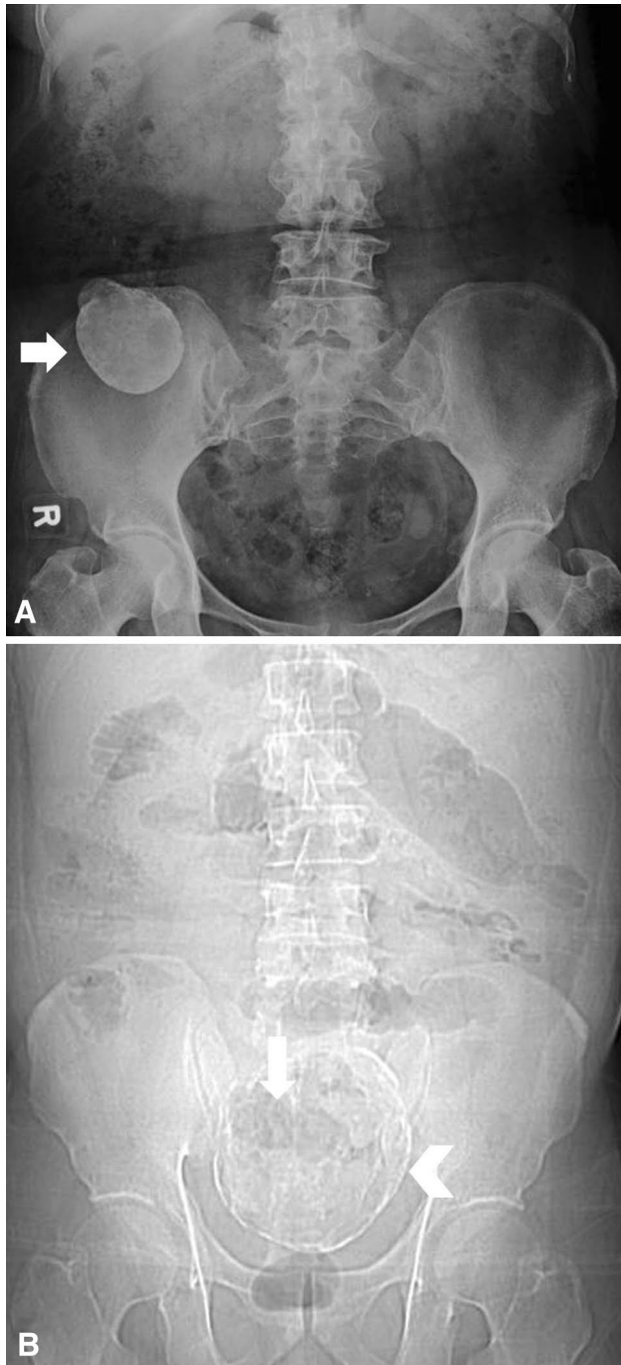


Fig. 1 Two patients with calcified Meckel's diverticulum detected on plain radiograph. **a** Radio-opaque oval structure at the right lower abdomen (*arrow*) consistent with calcified thick content inside the diverticulum. It was diagnosed as appendiceal mucocele, but surgery confirmed calcified Meckel's diverticulum. **b** Oval structure with egg-shell calcification (*arrowhead*) and internal gas (*arrow*) at the mid-lower pelvis. The final diagnosis is complicated Meckel's diverticulum

Differentiation between Meckel's diverticulum and acquired diverticula

Meckel's diverticulum is usually a single diverticulum arising from the antimesenteric border of the distal ileum, typically 40–100 cm from the ileocecal valve, while acquired diverticula are varied in terms of number, location, point of attachment to small bowel (usually arising from the mesenteric border), and lack of junctional fold pattern (Fig. 5). The appendix is also a blind-ending pouch, longer and narrower than Meckel's diverticulum, with typical location.

Computed tomography

Meckel's diverticulum, if small, is quite difficult to distinguish from normal ileal loops in uncomplicated cases. If it is >3 cm in diameter, it appears as a blind-ending gas- or fluid-filled structure. CT is considered to be the imaging modality of choice in the diagnosis of complicated Meckel's diverticulum. Recently, modern multidetector CT (MDCT) allows high-resolution images, with supplementary multiplanar reconstructed images providing the best depiction of Meckel's diverticulum, which is often concealed by adjacent small-bowel loops. Particularly ileal continuation of diverticula is detected on oblique coronal or sagittal views (Fig. 6).

Angiography

Angiography can show persistent vitelline artery, which typically arises from mid or distal branches of the SMA. Occasionally, this artery can be visualized by MDCT (Fig. 6). Heterotopic gastric mucosa may demonstrate dense blush. Extravasation of contrast material in case of active GI bleeding typically requires bleeding at a rate of at least 0.5 ml/min in order to be visualized [9].

Scintigraphy

Radionuclide scan may provide a clue to diagnose Meckel's diverticulum with complication. To identify the site of heterotopic gastric mucosa, ^{99m}Tc -pertechnetate is taken up by the heterotopic gastric mucosa in the diverticulum. Higher sensitivity in children (85–90 %) than in adults (60 %) is reported [10]. To identify the site of GI bleeding, ^{99m}Tc -sulfur colloid or erythrocyte labelled

Fig. 2 Junctional fold pattern. **a** Triradiate fold pattern when surrounding bowel is collapsed (*short arrow*). **b** Mucosal triangular plateau pattern when surrounding bowel is distended (*long arrows*)

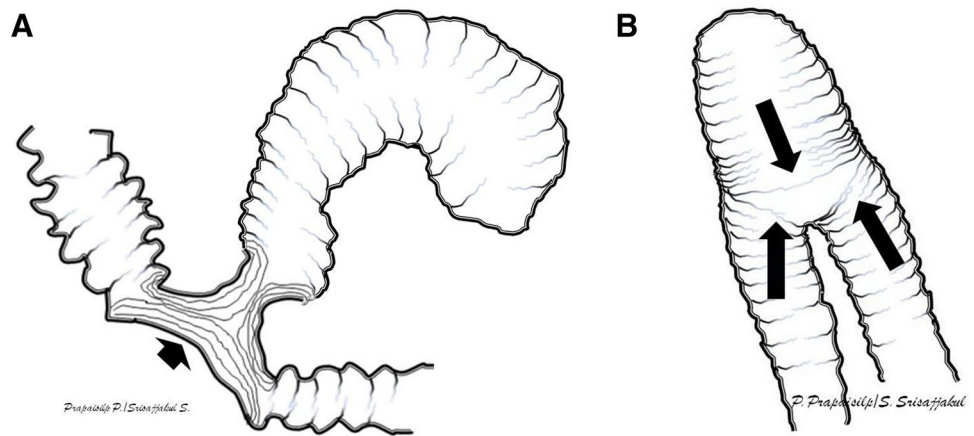


Fig. 3 Barium examination shows blind-ended structure arising from the antimesenteric border of the distal ileal loop (*arrowhead*). Visualization of the triradiate fold pattern (*arrow*), in which adjacent ileal loops are collapsed

with the same tracer can be performed. Accumulation of radionuclide substance in the typical location of Meckel's diverticulum is consistent with a diverticulum with hemorrhage, in which the diverticulum must be actively bleeding at a rate of at least 0.1 ml/min. Identifying bleeding on scintigraphy is sensitive but not specific. Bleeding may be detected, but the source may not be Meckel's diverticulum; however, specificity reaches 100 % if findings on a subsequent scintigraphy for heterotopic gastric mucosa is positive.

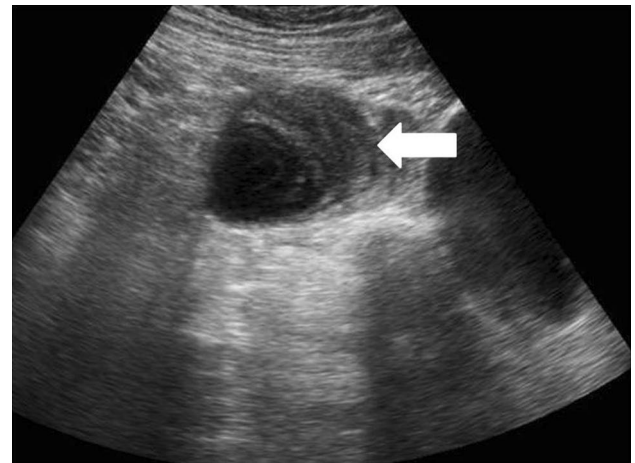


Fig. 4 Gray-scale sonogram shows oval hypoechoic structure in transverse plane, surgically confirmed as obstructed Meckel's diverticulum. Fluid-filled, thick-layered content (*arrow*) is visible

Complications of Meckel's diverticulum

In the majority of patients, Meckel's diverticulum is asymptomatic. Risk of complications (produce symptoms) varies, ranging from 4 to 25 % [11].

Common complications

Hemorrhage

Hemorrhage is the most common complication of Meckel's diverticulum, and it is more frequent in young children.

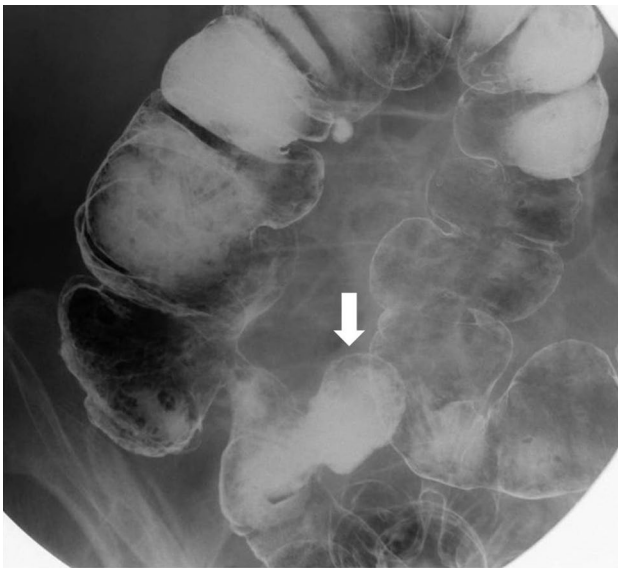


Fig. 5 Barium examination demonstrates acquired or pseudodiverticula arising from the mesenteric border of the terminal ileum proximal to the ileocecal valve, with no junctional fold pattern (*arrow*)



Fig. 6 Sagittal CT of the abdomen shows Meckel's diverticulum (*arrow*) arising from an ileal loop, with moderately wide neck. The primitive vitelline artery arising from the ileal branch of the SMA is detected along the wall of the diverticulum (*black arrowheads*)

Two possible mechanisms include peptic ulcer formation in the heterotopic gastric mucosa in diverticula and damage to the adjacent ileal mucosa by hyperacidity.

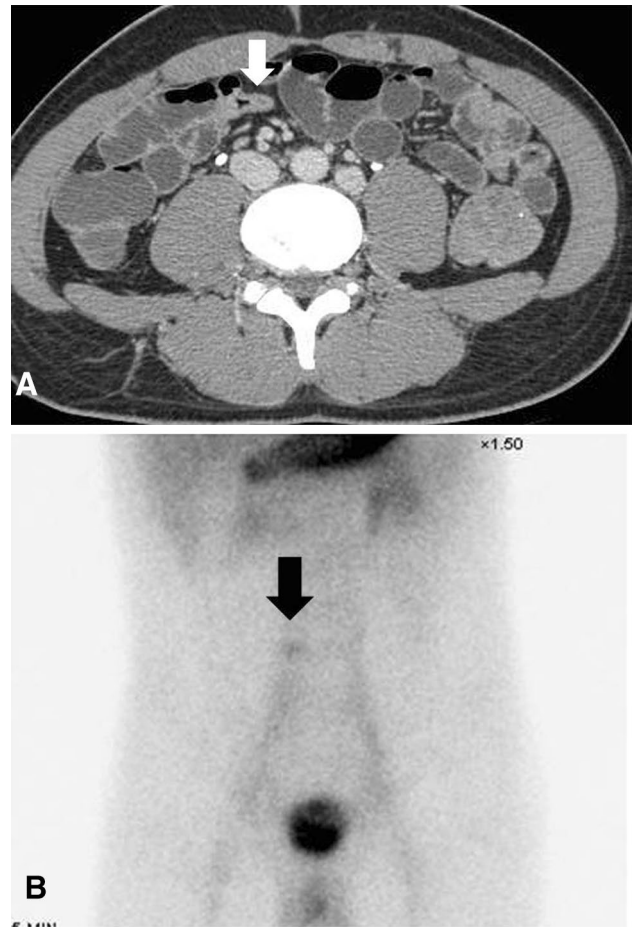


Fig. 7 **a** Axial CT of the abdomen shows an outpouching lesion from the ileal loop, with thickened mucosa and increased enhancement (*arrow*). **b** ^{99m}Tc-pertechnetate scan shows the focus of moderately increased uptake in the mid abdomen (*arrow*), corresponding to the location seen on CT—a finding compatible with a Meckel's diverticulum containing ectopic gastric mucosa

^{99m}Tc-pertechnetate scintigraphy is the imaging modality of choice (Fig. 7). Extravasation of contrast media at the diverticular neck with delayed contrast accumulation into the blind-ended structure attached to the distal ileum is the imaging hallmark on CT in active bleeding cases. In chronic or intermittent bleeding, it may show mural thickening of these diverticula.

Bowel obstruction

Bowel obstruction is the second most common complication of Meckel's diverticulum and is the consequence of ulceration and fibrosing stenosis of the attached ileum due to acid secretion by heterotopic tissue in the diverticulum. Other mechanisms include incarceration of bowel loops beneath the fibrous band connecting the diverticulum to the

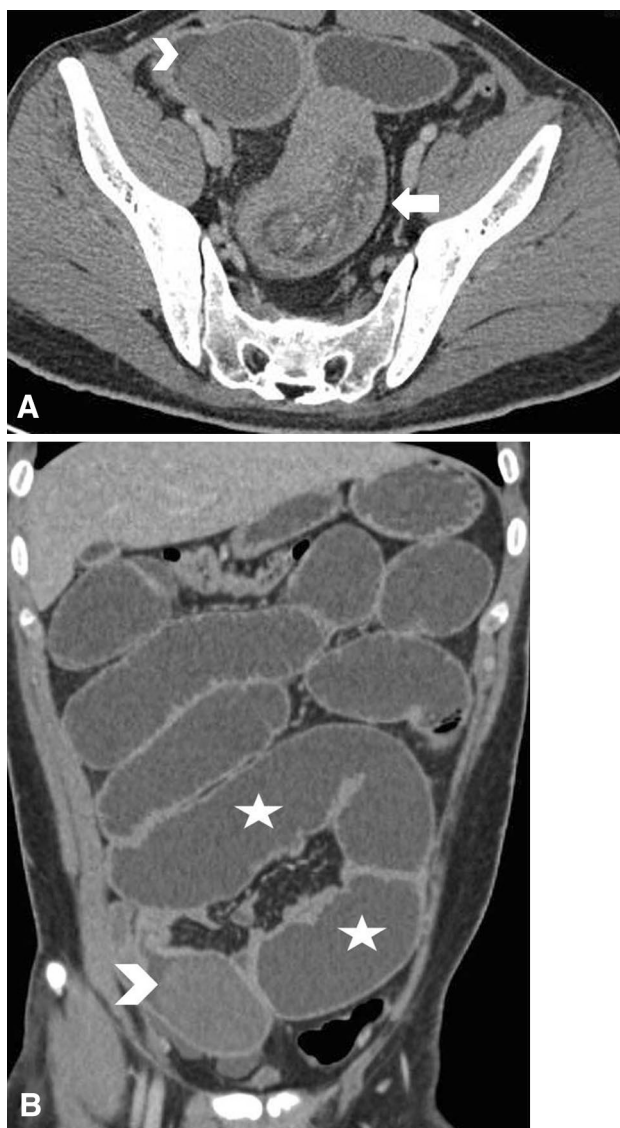


Fig. 8 **a** Axial CT shows an inverted diverticulum containing hyperdensity fluid (*arrowhead*) that serves as the lead point of ileoileal intussusception (*arrow*). **b** Coronal CT in the same patient (different location from intussusception) also shows inverted diverticulum (*arrowhead*) with small-bowel dilatation (*star*), consistent with small-bowel obstruction

umbilical region, diverticula inversion causing intraluminal obstruction or functioning as a lead point to an ileoileal intussusceptions (Fig. 8), and extension into a hernia sac (Littre's hernia). CT is the imaging modality of choice for the workup of this complication.

Diverticulitis

Diverticulitis accounts for up to 30 % of symptomatic cases [12]. It may clinically mimic acute appendicitis.

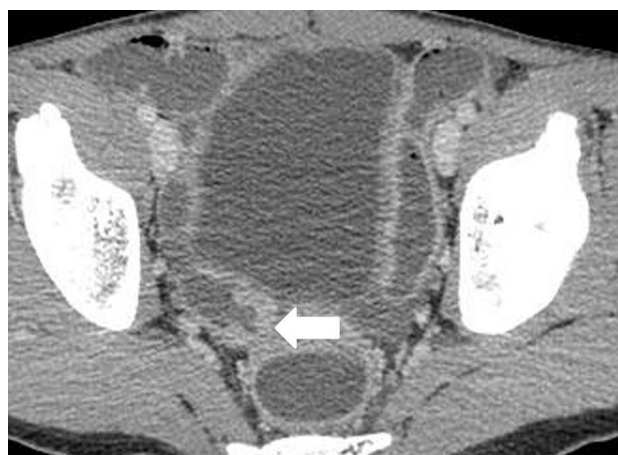


Fig. 9 Contrast-enhanced CT of lower abdomen shows blind-ending, tubular Meckel's diverticulum with thickened mucosal fold (*arrow*). Pathology confirmed ectopic gastric mucosa in Meckel's diverticulum

Pathogenesis commonly occurs secondary to inflammation caused by acid secretion, luminal obstruction identical to those of acute appendicitis caused by enteroliths, or neoplasm. Scintigraphy has been performed to diagnose Meckel's diverticulitis caused by heterotopic gastric mucosa and usually shows a localized increased uptake [13]. CT is the preferred imaging modality, which usually depicts a blind-ended pouch of variable size with increased mural thickness (Fig. 9), increased diverticular wall enhancement, and air, fluid, or internal content surrounded by mesenteric inflammation. In more severe cases, abscess can develop (Fig. 10).

Uncommon complications

Enterolith formation

Enterolith formation is an uncommon complication and can be seen in 3–10 % of Meckel's diverticulum [12]. Enteroliths are assumed to form as a result of stasis and manifest as peripheral calcification with a radiolucent center and, less often, have a laminated pattern. Plain film and unenhanced CT should be more valuable in detecting an enterolith.

Perforation

Perforation is a serious complication and usually secondary to diverticulitis, gangrene, and peptic ulcer [12]. The presence of pneumoperitoneum in the setting of Meckel's diverticulum is the imaging consideration.

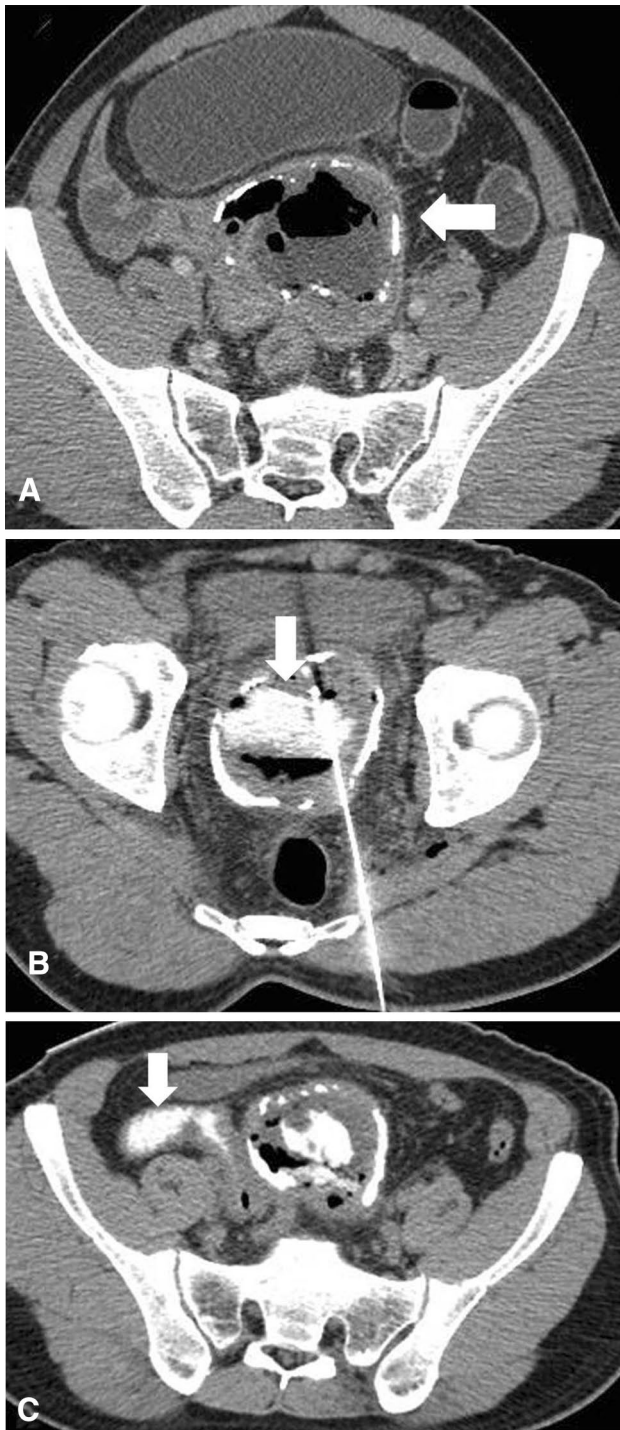


Fig. 10 Complicated Meckel's diverticulitis with abscess formation. **a** The same patient as in Fig. 1b, shows rounded lesion with air–fluid level and calcified wall (arrow). **b, c** During percutaneous drainage, positive contrast is introduced into the abscess (arrow in **b**), with ileal communication (arrow in **c**)

Neoplasm

Neoplasm is a rare complication, accounting for up to 3 % of complicated cases [14]. Carcinoid tumor is the most



Fig. 11 Coronal CT of the abdomen shows a heterogeneous hypervascular mass arising from Meckel's diverticulum (arrow). Pathology confirmed carcinoid tumor in Meckel's diverticulum

frequently reported neoplasm complicating Meckel's diverticulum (Fig. 11). Other tumors include leiomyoma, leiomyosarcoma, and adenocarcinoma. Imaging features are nonspecific.

Compliance with ethical standards

Conflict of interest None.

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