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Meckel's diverticulum is the congenital persistence of all or part of the omphalomesenteric duct, also referred to as the vitelline duct or yolk stalk. The omphalomesenteric duct is the primitive connection between the fetal yolk sac and developing midgut. At approximately week 5–7 of fetal gestation, this connection regresses as the placenta grows to become the main source of nutrition for the developing embryo. Incomplete regression leads to malformations such as a fibrous band, persistent sinus, cysts, omphaloenteric fistula, or most commonly a Meckel's diverticulum. It is a true diverticulum, consisting of all intestinal layers. Paired right and left vitelline arteries are branches of the primitive aorta and accompany the omphalomesenteric duct. The right vitelline artery eventually becomes the superior mesenteric artery and will provide a terminal branch to the diverticulum. The left vitelline artery involutes, but any vitelline arterial remnant that fails to obliterate completely will form fibrous bands connecting the gut to the abdominal wall. Ectopic tissue can be found in the diverticulum, and its presence often is what leads to the clinical presentation. Commonly reported types of ectopic tissue are primarily gastric or pancreatic in origin. However, isolated series have documented the presence of ectopic endometrial, colonic, or duodenal tissue.

The “rule of 2s” is well known in pediatric surgery and is used to describe a Meckel's diverticulum: The incidence is roughly 2 % of the population. If symptomatic, it is gener-

ally recognized by 2 years of age. It is 2 in. in maximal dimension and is located within 2 ft of the ileocecal valve, but these measurements vary significantly in the reported literature. One of two types of heterotopic tissue is commonly found within the diverticulum, including the gastric and pancreatic tissue.

Meckel's diverticulum can be symptomatic or asymptomatic. There are critical differences in terms of the age of presentation, acuity, associated abnormalities, and treatment depending on the presentation. Most often it will have been encountered at celiotomy for another cause and is merely an incidental finding. Symptomatic Meckel's diverticula, however, are occasionally difficult to diagnose, are higher acuity, and involve a more complex treatment strategy. Symptomatic Meckel's diverticula are usually present in the form of bleeding, inflammation, or obstruction. The different presentation, diagnosis, and eventual treatment for each of these presentation styles are varied, but most often involve surgical treatment.

Gastrointestinal Hemorrhage

The most common manifestation of a Meckel's diverticulum is bleeding. This is typically due to the ectopic gastric tissue within the diverticulum, which causes ulceration in the adjacent normal ileal mucosa. The ulcer is generally located just distal to the diverticulum. These patients classically present with painless, episodic bright red blood per rectum, which can be massive and associated with profound blood loss and low hematocrit. The majority of patients with a bleeding Meckel's diverticulum will present within the first 3 years of age. Among all children with gastrointestinal hemorrhage, roughly half are attributable to a Meckel's diverticulum.

Initially, these patients need to be resuscitated and are often given blood products. In order to confirm the diagnosis, the patient should be administered a technetium-99m pertechnetate nuclear medicine scan. In most cases this will visualize the heterotopic gastric tissue distant from the

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stomach. Occasionally, the pertechnetate scan does not perfectly visualize the heterotopic tissue. To enhance the scan and increase its sensitivity, some administer pentagastrin or an H₂ receptor blocker. These drugs enhance the uptake of the technetium-99m pertechnetate or prevent its expulsion from gastric mucosal cells. Re-scanning after a non-diagnostic study can also sometimes be useful. Other methods of detection, especially tagged-RBC scans or angiography, are generally less helpful, unless the rate of bleeding at the time of the test is sufficient to detect blood loss of at least 0.5 mL/min. If the clinical suspicion remains high despite a negative Meckel's scan, diagnostic laparoscopy is indicated.

The mainstay of treatment for a bleeding Meckel's diverticulum after appropriate resuscitation is surgical resection. Laparoscopic, single-incision laparoscopic, or open approaches are acceptable, depending on surgeon preference. Generally, a mini-laparotomy or a laparoscopic approach with eventual enlargement of a trocar site can permit easier extracorporeal segmental resection and anastomosis. It is important to visually inspect the diverticulum and palpate for any thickened or inflamed tissue. Thickened tissue within the diverticulum or at its base likely represents heterotopic tissue, while thickened distal bowel likely contains the inflamed, marginal ulcer. Especially in a patient who presented with bleeding, it is vital to resect the diverticulum along with any ulcerated tissue found adjacent to the Meckel's diverticulum, as failure to do so greatly increases morbidity and the chance for re-operation. The subsequent anastomosis should be between two healthy appearing ends of bowel and can be performed as a hand-sewn end-to-end anastomosis or a side-to-side anastomosis with a GIA stapler.

Postoperative care is routine and depending on the amount of bowel manipulation have differing rates of postoperative ileus. Need for re-operation and wound infection are uncommon complications for patients with bleeding from a Meckel's diverticulum.

Bowel Obstruction

Patients with a symptomatic Meckel's diverticulum can present with symptoms related to an obstructive process of the bowel. However, Meckel's diverticulum may not be the highest entity on a clinician's differential diagnosis in patients with nausea, vomiting, intermittent abdominal pain, or bloody stools. This is because intussusception, small bowel volvulus, internal hernia, and other obstructive processes are usually encountered outside the context of Meckel's diverticulum. Obstruction due to Meckel's diverticulum often presents within the first year of life.

Ileoileal and subsequent ileocolic intussusception, with the diverticulum serving as a lead point, is the most common cause of intestinal obstruction related to a Meckel's diver-

ticulum. However, it is usually at operation that this is discovered. These patients present with symptoms of intussusception—vomiting, intermittent colicky abdominal pain, bloody stools, and occasionally a palpable left lower quadrant mass—and should be treated along the typical intussusception algorithm. This occurs most often during infancy or early childhood. When a Meckel's diverticulum is the lead point, routine reduction with air or contrast enemas is unlikely to be successful, and surgery is generally required. Diagnostic laparoscopy or laparotomy reveals the Meckel's diverticulum as the cause.

Small bowel volvulus and internal hernia are also possible and should be treated as surgical emergencies. Importantly these patients present with pain out of proportion to abdominal examination findings and do not have a history of prior abdominal surgery. These patients should be resuscitated, given intravenous antibiotics, and taken to the OR urgently for abdominal exploration. A Meckel's diverticulum or another malformation related to the embryonic vitelline duct may be encountered. This might be in the form of a volvulus around a fibrous band connecting the Meckel's diverticulum to the abdominal wall or an internal hernia between the diverticulum and a mesodiverticular artery with a separate loop of bowel trapped within it (Fig. 54.1).

Inflammatory Process

Perhaps the most elusive symptomatic presentation of a Meckel's diverticulum is an acute intra-abdominal inflammatory process, which is known to mimic appendicitis, Crohn's disease, ulcerative colitis, or even gastroenteritis.

This presentation is more common in older children. Generally the history is very similar to that of acute appendicitis, with vague abdominal pain progressing to localized abdominal pain accompanied by fevers, chills, anorexia, and nausea. The pathophysiology is very similar to that of appendicitis. Ultrasound (US) or computed tomography (CT) of the abdomen may also demonstrate findings felt to be consistent with acute appendicitis, with the correct diagnosis not recognized until the operation. If a patient is being taken for appendectomy and the operative findings of the appendix do not appear to match the preoperative presentation or scan, the surgeon should keep the diagnosis of an inflamed Meckel's diverticulum in mind and carefully inspect the abdomen prior to closing.

The technical details of operation are similar regardless of presentation. In the case of inflammation, if the adjacent bowel appears healthy and is palpated to be normal, a stapled diverticulectomy is reasonable. In the case of perforation of the diverticulum with peritonitis, segmental bowel resection with primary anastomosis is safe. Stoma creation is very rarely indicated.

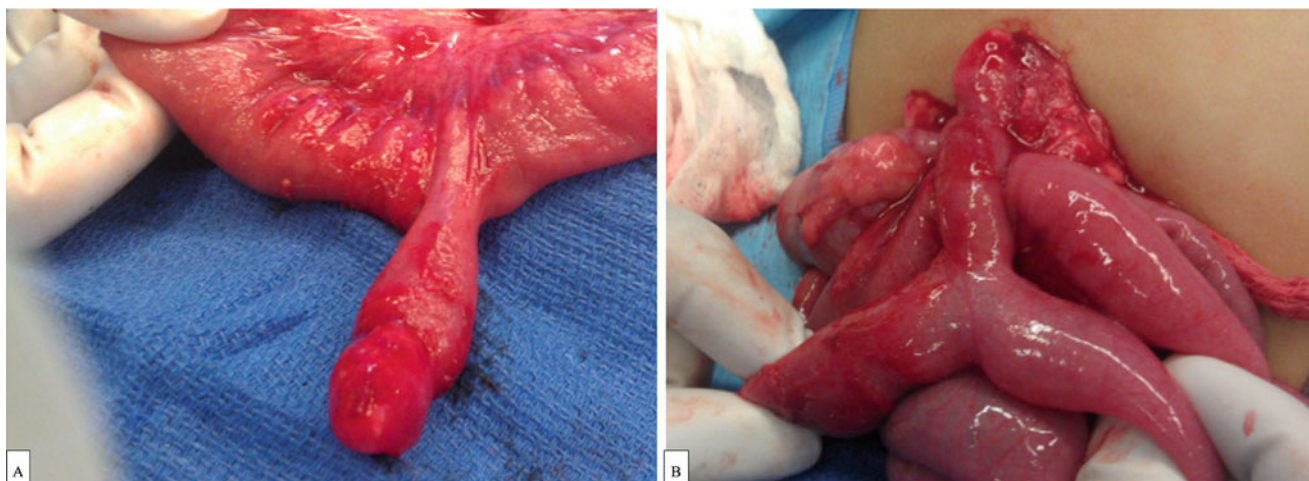


Fig. 54.1 Meckel's diverticula that arise from the antimesenteric border of the ileum. (a) Inflamed Meckel's diverticulum. (b) Meckel's diverticulum with a fibrous connection to the abdominal wall and an internal hernia causing obstruction

Incidental Meckel's Diverticulum

While there is little controversy over the surgical treatment of a symptomatic Meckel's diverticulum, there is no consensus on whether to remove incidentally found diverticula. In the case of a healthy appearing diverticulum without fibrous bands attached to the abdominal wall, we would advocate leaving them alone. However, if ectopic tissue or a mass can be palpated in the diverticulum or if it is adherent to the adjacent bowel or abdominal wall, it should be resected. Similarly, in the case of operation for suspected appendicitis, if a mildly inflamed appendix is found and a Meckel's diverticulum identified, the diverticulum should be removed (Figs. 54.2 and 54.3).

Atypical Presentation

One interesting presentation is that of a Littré hernia, occurring when a Meckel's diverticulum is found within an incarcerated hernia. First described in 1700 by Alexis Littré, this rare entity is described as a painful groin mass that is not accompanied by obstruction or peritonitis and most commonly occurs in inguinal and femoral hernias. These should be resected and the hernia repaired in the usual fashion.

Persistent sinuses and omphaloenteric fistula generally present with drainage from the umbilicus. In the case of a persistent sinus, the drainage can be serous or purulent, whereas enteric drainage represents an enterocutaneous fistula. If granulation tissue is present, some surgeons have advocated for silver nitrate application in the office. A patent urachus is also within the differential diagnosis, especially for those with straw-colored drainage. A fistulogram can confirm the course of any connection to the bowel or bladder

and help with operative planning. Foreign bodies can become lodged within Meckel's diverticula, and there have been reports of toothpicks, coins, seeds, and even a fish bone found at operation. Though much less pertinent in children, Meckel's diverticula have been associated with various malignancies, including carcinoid tumors, adenocarcinomas, gastrointestinal stromal tumors (GIST), sarcomas, and lymphomas. However, the mean age at presentation is between the fourth and sixth decades of life.

Summary

Meckel's diverticulum is the most common congenital malformation of the gastrointestinal tract and is part of a spectrum of anomalies that derive from a persistent omphalomesenteric duct. It is most often an incidental finding, but most symptomatic patients present with gastrointestinal bleeding, obstruction, or inflammation, the likelihood of each varying with age: <1 year of age for umbilical pathology, 0–1 year of age for obstruction, 1–3 years of age for gastrointestinal hemorrhage, and 7–9 years of age for inflammation. Heterotopic gastric and pancreatic tissue is frequently found within the diverticulum. The secretion of acid or enzymes from this tissue is thought to be the cause of bleeding from and inflammation of the diverticulum and surrounding tissue. A Meckel's scan using technetium-99m pertechnetate scintigraphy can localize the heterotopic tissue in the diverticulum. When symptomatic, resection is indicated, and any associated ulcerated or inflamed small bowel should be resected as well. Controversy still exists regarding the resection of asymptomatic, incidentally found Meckel's diverticulum. We recommend leaving them when asymptomatic and no mass is palpable within it. Complications are rare but include ileus, wound infection, incomplete diverticulectomy, and adhesive bowel obstruction.

Clinical Pathway for Meckel's Diverticulum

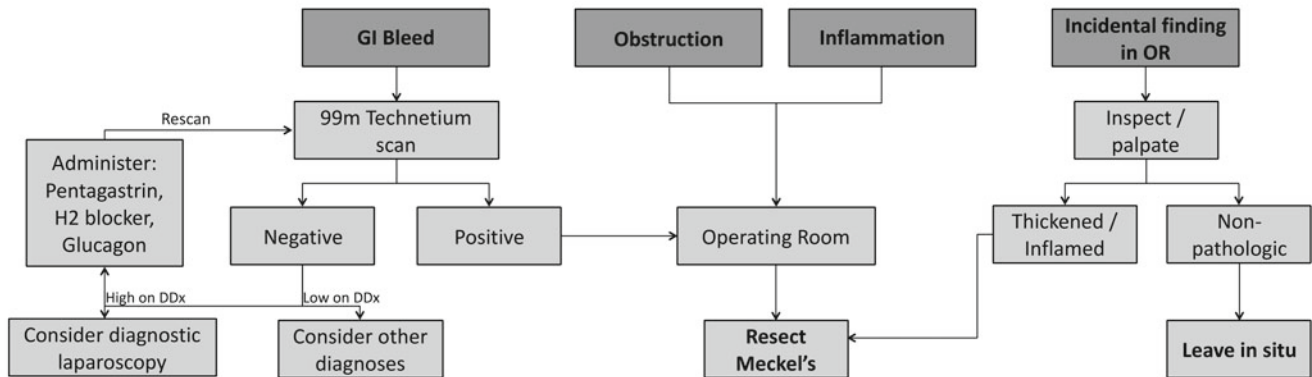


Fig. 54.2 Clinical pathway treatment strategy for patients with presentations consistent with symptoms from Meckel's diverticula

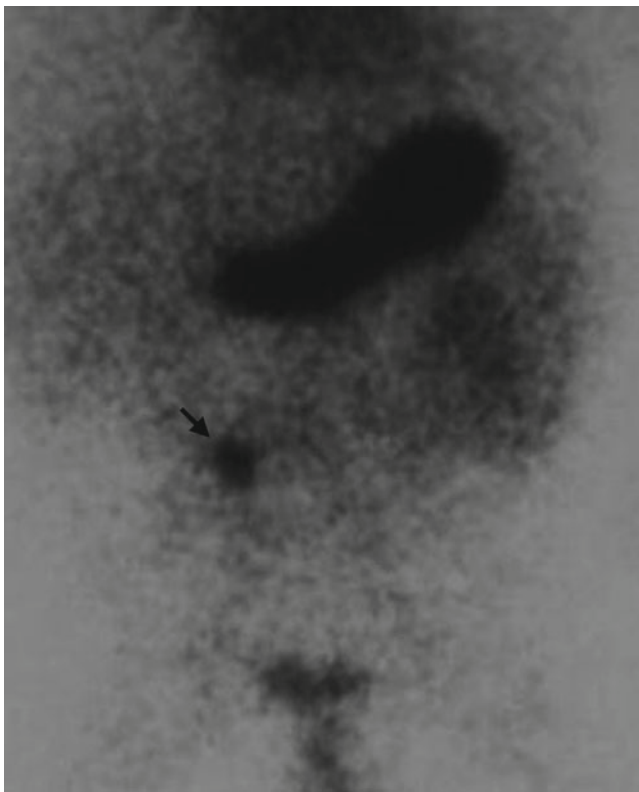


Fig. 54.3 Technetium-99m pertechnetate "Meckel's scan" showing uptake in the stomach as well as heterotopic gastric uptake in the *right lower quadrant* (Reprinted from Caro P, Ryan S. Small Bowel Normal Anatomy and Congenital Anomalies. *Abdom Imaging*. 2013;537–50, with kind permission from Springer Science and Business Media)

Editor's Comment

Meckel's diverticulum is a simple defect that can cause big problems. Except when it causes gastrointestinal bleeding, the diagnosis is usually made in the operating

room when a child undergoes an exploration for bowel obstruction, intussusception, volvulus, or an acute inflammatory process that looks very much like acute appendicitis. In fact, the presence of a Meckel's diverticulum should be considered in any patient with an atypical presentation and should be carefully sought for when the findings at exploration are anything other than what was expected. The distal meter or so of the ileum should be inspected carefully, as it is not always easily apparent and the location is highly variable. While an asymptomatic diverticulum found incidentally should probably be left alone, unless it is tethered to the abdominal wall or there is a mass, a simple diverticulectomy performed with a GIA stapler oriented transversely across the base is quick and generally quite safe.

The "Meckel's scan" demonstrates gastric mucosa and therefore is only indicated in patients who are bleeding. It is not 100 % sensitive either, so if the clinical suspicion remains high after a negative scan, diagnostic laparoscopy should be considered. For most symptomatic diverticula, a minimal-access approach is best, as the diverticulum can usually be mobilized laparoscopically and then delivered through a small periumbilical incision. When a Meckel's diverticulum is suspected preoperatively, it is probably safer to place the first trocar away from the midline, as the diverticulum is sometimes adherent to the undersurface of the umbilicus where it can be easily injured. Bowel resection with primary anastomosis is necessary for the short diverticulum with a large mass of ectopic tissue or when an inflammatory process involves the base. Bowel resection is also recommended for bleeding to ensure that the portion of the adjacent ileum containing the ulcer is removed with the specimen. Ileostomy is almost never necessary when dealing with a complication of a Meckel's diverticulum.

Suggested Reading

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