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Meckel's Diverticulum: An In-Depth Review of Pathophysiology, Clinical Presentation, Diagnostic Modalities, and Therapeutic Interventions

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ABSTRACT

Background: Meckel's diverticulum is the most prevalent congenital anomaly of the gastrointestinal tract, resulting from the incomplete obliteration of the omphalomesenteric duct during fetal development. Although often asymptomatic, it can present with a variety of complications, including bleeding, obstruction, and inflammation, necessitating timely and accurate diagnosis and intervention.

Objective: This article aims to provide a comprehensive overview of Meckel's diverticulum, including its embryological origin, pathophysiological features, clinical manifestations, diagnostic strategies, and therapeutic approaches.

Methods: A thorough literature review was conducted, focusing on studies and case reports detailing the clinical presentation, imaging modalities, surgical techniques, and outcomes associated with Meckel's diverticulum. Key databases such as PubMed, Scopus, and Web of Science were searched for relevant articles published up to August 2024.

Results: Meckel's diverticulum typically presents in childhood but can manifest at any age. Its clinical presentation ranges from asymptomatic incidental findings to acute abdomen scenarios due to complications like hemorrhage, intestinal obstruction, diverticulitis, and, rarely, neoplastic transformation. Diagnostic imaging, including technetium-99m pertechnetate scintigraphy (Meckel's scan), CT, and MRI, plays a crucial role in the preoperative identification of the diverticulum. The management of symptomatic Meckel's diverticulum is predominantly surgical, with laparoscopic and open approaches being widely utilized. Prophylactic resection in asymptomatic cases remains controversial, with decision-making guided by patient-specific factors such as age, diverticulum characteristics, and the presence of ectopic tissue.

Conclusion: Meckel's diverticulum, though often a silent anomaly, can present with significant clinical challenges. Early recognition and appropriate management are essential for optimal patient outcomes. This review highlights the importance of a multidisciplinary approach involving pediatricians, surgeons, and radiologists in the diagnosis and treatment of this condition.

KEYWORDS: Meckel's Diverticulum, Gastrointestinal Anomaly, Omphalomesenteric Duct

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INTRODUCTION

Meckel's diverticulum, named after the German anatomist Johann Friedrich Meckel, is the most common congenital anomaly of the gastrointestinal tract, occurring in approximately 2% of the population. It arises due to the incomplete obliteration of the vitelline duct, also known as the omphalomesenteric duct, during embryonic development. The persistence of this ductal remnant leads to the formation of a true diverticulum, which contains all layers of the intestinal wall.1,2

The clinical spectrum of Meckel's diverticulum is diverse, with many individuals remaining asymptomatic throughout their lives. However, complications can arise, particularly in children and young adults, presenting a diagnostic challenge. The most common complications include gastrointestinal bleeding, often due to the presence of ectopic gastric mucosa,

intestinal obstruction caused by intussusception or volvulus, and inflammation mimicking acute appendicitis. Less commonly, Meckel's diverticulum can harbor neoplasms, further complicating its clinical course.1,2,3

Despite being a relatively common anomaly, the diagnosis of Meckel's diverticulum is often delayed due to its nonspecific presentation and the rarity of symptomatic cases. Advanced imaging techniques and a high index of clinical suspicion are essential for accurate diagnosis. The management strategy primarily involves surgical intervention, particularly in symptomatic patients. However, the indication for resection in asymptomatic individuals remains a topic of ongoing debate.4,5

This article aims to elucidate the current understanding of Meckel's diverticulum, encompassing its embryological basis, clinical manifestations, diagnostic challenges, and therapeutic strategies. We will explore the latest advancements in diagnostic imaging and surgical techniques, providing a comprehensive review of the literature to guide clinical practice.4,5

Epidemiology of Meckel's Diverticulum

Meckel's diverticulum is recognized as the most prevalent congenital anomaly of the gastrointestinal tract, with an estimated incidence of approximately 2% in the general population. This vestigial remnant of the omphalomesenteric duct, which fails to involute completely during embryogenesis, has been found to present equally among all ethnicities and geographic regions, indicating a lack of predilection based on genetic or environmental factors.6

Prevalence and Incidence: The prevalence of Meckel's diverticulum has been consistently reported across numerous studies, primarily arising from autopsy and surgical data. The incidence in autopsy series varies slightly, often cited between 1% and 3%. However, it is worth noting that the true prevalence might be underestimated due to the high number of asymptomatic cases that go undetected throughout life. The incidence rate does not show significant variation between genders; however, males are more likely to develop symptomatic presentations. The male-to-female ratio for symptomatic cases is reported to range from 2:1 to 4:1, which is particularly evident in pediatric populations where complications such as bleeding and obstruction are more common.6,7

Age Distribution: Meckel's diverticulum can present at any age, but the likelihood of developing symptoms tends to decrease with advancing age. The majority of symptomatic cases are diagnosed in the pediatric population, with the highest incidence observed in children under 10 years of age. In adults, the diverticulum often remains asymptomatic and is frequently discovered incidentally during imaging or surgery for unrelated conditions. Despite this, adults may still present with complications, particularly bleeding and obstruction, albeit at a lower frequency than in children. 6,7

Complication Rates: The risk of complications associated with Meckel's diverticulum is generally low, with symptomatic cases occurring in approximately 4% to 6% of individuals with the anomaly. The most common complication is gastrointestinal bleeding, which occurs due to the presence of ectopic gastric mucosa secreting acid, leading to ulceration of adjacent ileal mucosa. This complication predominantly affects children and is the leading cause of painless rectal bleeding in this age group. Intestinal obstruction, resulting from intussusception, volvulus, or entrapment of the diverticulum by fibrous bands, represents the second most common complication and is more frequent in children and young adults. Diverticulitis, which mimics acute appendicitis, and the rare occurrence of neoplasms, including carcinoid tumors and adenocarcinomas, add to the spectrum of complications, albeit these are less commonly observed.6,7,8

Geographic and Ethnic Variability: There is no significant geographic or ethnic variability reported in the incidence of Meckel's diverticulum, suggesting a uniform distribution globally. The anomaly appears to be equally prevalent across diverse populations, which aligns with its congenital nature and lack of environmental or lifestyle influences on its development.7,8

Familial Patterns: While Meckel's diverticulum itself is a congenital anomaly rather than a hereditary condition, there have been isolated reports of familial clustering. These instances, however, are rare and do not suggest a clear pattern of inheritance. The lack of strong familial predisposition further supports the hypothesis that Meckel's diverticulum arises sporadically due to developmental anomalies during embryogenesis. 9,10

Clinical Implications: Understanding the epidemiology of Meckel's diverticulum is crucial for clinicians, particularly in pediatric and emergency medicine, as it aids in maintaining a high index of suspicion for this condition in relevant clinical scenarios. The awareness of its relatively higher prevalence and potential for serious complications can facilitate timely diagnosis and intervention, ultimately improving patient outcomes.11

In summary, Meckel's diverticulum is a relatively common congenital gastrointestinal anomaly with a significant male predominance in symptomatic cases and a higher incidence of complications in the pediatric population. Despite its uniform global distribution and sporadic occurrence, it presents a clinically important consideration due to the range of potential complications that may arise.12

CASE PRESENTATION

Patient: Male, 23 years old, originally from Iguala, Guerrero. Past Medical History: Denies chronic degenerative diseases, allergies, previous surgeries, and regular smoking. Occasional alcohol consumption without reaching intoxication. Other histories are unremarkable.

Current Illness: The patient presented two days prior to admission to the emergency department with a 6/10 epigastric pain on the visual analog scale, accompanied by nausea without vomiting. He self-medicated with paracetamol, but the pain did not improve. The pain later migrated to the right iliac fossa and increased in intensity, accompanied by two episodes of vomiting, prompting him to seek medical attention. Upon admission to the emergency department, the following vital signs were recorded: heart rate 97 bpm, respiratory rate 22 breaths per minute, temperature 37.9°C, blood pressure 120/80 mmHg, and oxygen saturation 94%.

Physical Examination: The patient was alert and oriented, with normal skin and mucous membrane coloration. Cardiopulmonary examination was unremarkable. The abdomen was flat, with decreased bowel sounds. There was tenderness to both medium and deep palpation in the right iliac fossa, with a positive McBurney's point, rebound tenderness, and Rovsing's sign. The remainder of the examination was normal.

Laboratory Studies: The following results were obtained: white blood cells 14.64 x 10^3/µL, neutrophils 83.6%, hemoglobin 10.7 g/dL, platelets 360,000/µL. Urinalysis was unremarkable, and other tests were within normal limits.

Initial Diagnosis and Surgical Intervention: Based on the clinical presentation and evolution, acute appendicitis was suspected, and urgent surgical treatment was offered. The patient underwent an appendectomy with intestinal resection and end-to-end anastomosis.

During the surgical exploration, a McBurney incision was performed. The appendix appeared normal, with no signs of inflammation, but an appendectomy with Pouchet's management was completed. An exploration of approximately 200 cm of the small intestine, starting from the ileocecal valve, revealed a Meckel's diverticulum approximately 60 cm from the ileocecal valve on the antimesenteric border. The diverticulum measured approximately 2.5 x 2 cm and appeared erythematous.Figure 1

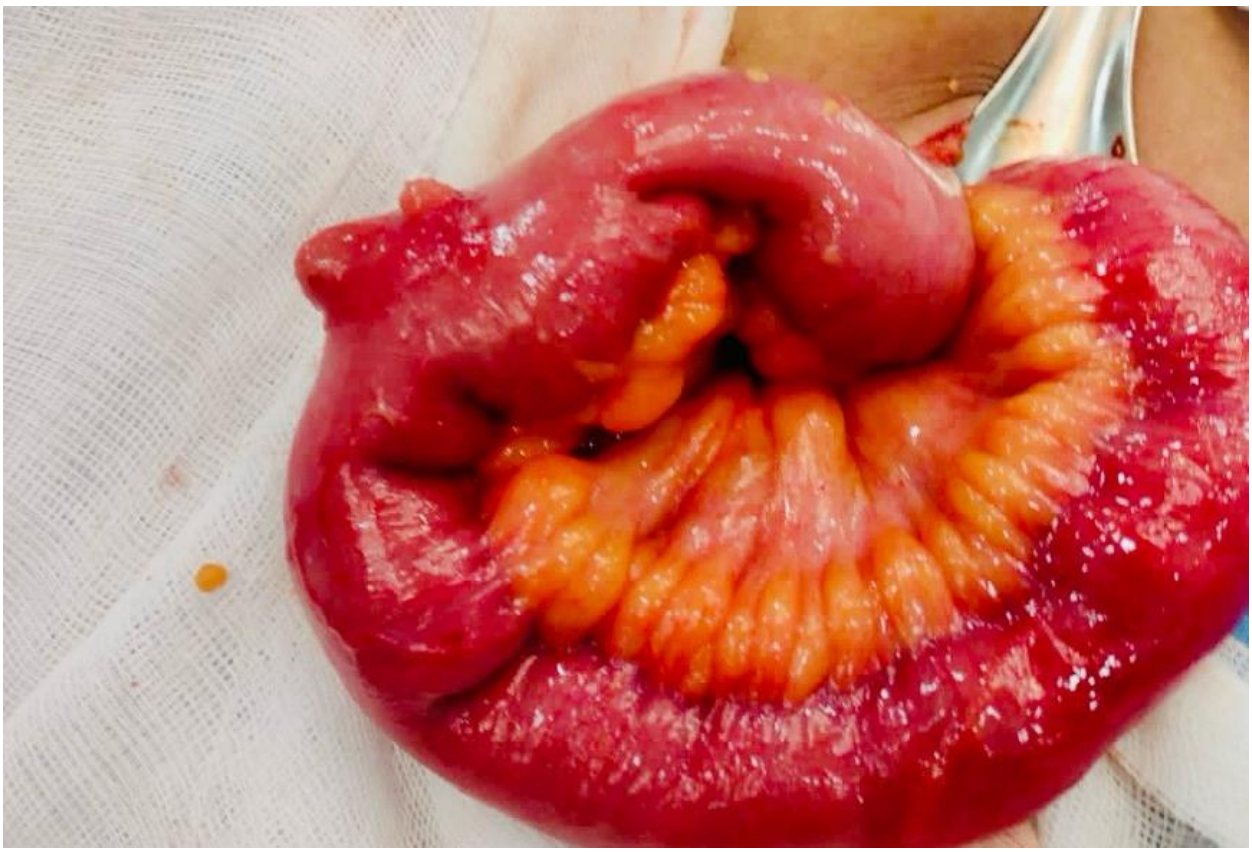

Figure 1. Meckel’s diverticulum.

A resection of approximately 5 cm of the ileum was performed, followed by a two-layer end-to-end enteroenteric anastomosis. Figure 2

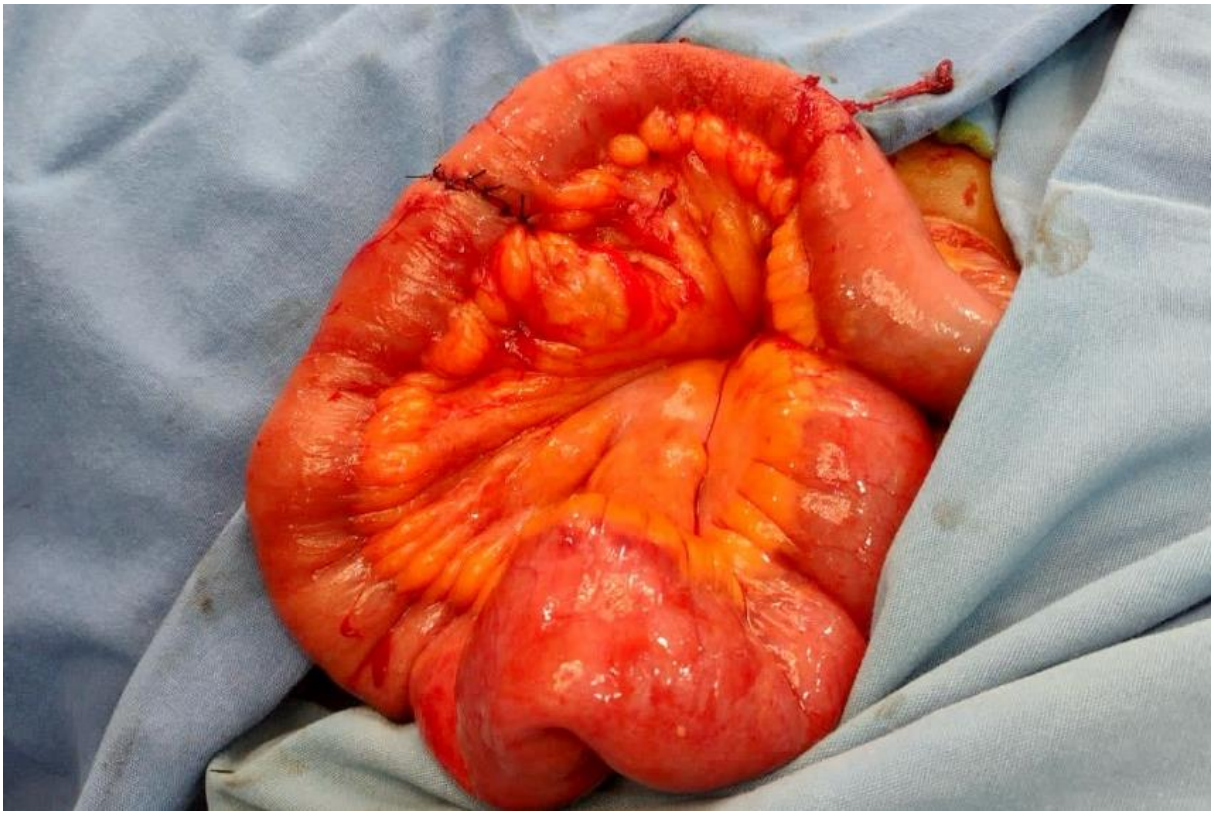

Figure 2. Enteroenteric anatomosis.

A Penrose drain was placed in the pelvic cavity, and the incision was closed in layers.

Postoperative Course: The patient began oral intake the following day with progressive diet advancement and ambulation, which were well tolerated. The drain was removed on the third day, and the patient was discharged on the fourth day without complications.

CONCLUSION

Meckel's diverticulum stands as a critical, albeit often silent, congenital anomaly of the gastrointestinal tract, with significant implications for clinical practice. This vestigial structure, arising from the incomplete obliteration of the omphalomesenteric duct during fetal development, represents a unique confluence of embryological, anatomical, and clinical considerations.

Despite its relatively high prevalence of approximately 2%, Meckel's diverticulum frequently remains asymptomatic, posing a diagnostic challenge. The heterogeneity in clinical presentation, ranging from incidental discovery to acute complications, underscores the importance of maintaining a high index of suspicion, particularly in pediatric populations where complications such as gastrointestinal bleeding, obstruction, and diverticulitis are more common. Notably, the presence of ectopic tissue, most frequently gastric mucosa, is a pivotal factor in the pathophysiology of these complications, contributing to ulcer formation and subsequent hemorrhage.

The diagnostic approach to Meckel's diverticulum necessitates a nuanced understanding of various imaging modalities. Technetium-99m pertechnetate scintigraphy remains a cornerstone for detecting ectopic gastric mucosa, especially in pediatric cases with unexplained gastrointestinal bleeding. However, the diagnostic utility of other imaging techniques, including computed tomography (CT) and magnetic resonance imaging (MRI), cannot be overstated, particularly in complicated presentations involving obstruction or inflammation. The advent of advanced endoscopic techniques further enhances the diagnostic armamentarium, offering both visual and therapeutic capabilities.

The management of Meckel's diverticulum is inherently guided by the presence or absence of symptoms. While asymptomatic cases often do not warrant intervention, the decision to perform prophylactic resection remains a subject of ongoing debate. Factors influencing this decision include the patient’s age, the length and diameter of the diverticulum, and the presence of ectopic tissue or previous complications. Symptomatic Meckel's diverticulum, on the other hand, typically necessitates surgical intervention, with laparoscopic resection emerging as the preferred approach due to its minimally invasive nature and favorable outcomes. The role of open surgery, though less common, remains critical in cases of complicated diverticulum where extensive adhesions or complications are present.

The long-term prognosis for patients with Meckel's diverticulum, particularly those who undergo surgical

resection, is generally excellent, with low recurrence rates and minimal postoperative complications. However, the potential for rare complications, including neoplastic transformation, warrants a thorough histopathological examination of resected specimens.

In conclusion, Meckel's diverticulum, while often asymptomatic, can present with life-threatening complications that require prompt recognition and intervention. The multifaceted nature of this anomaly, encompassing its embryological origin, clinical manifestations, diagnostic strategies, and therapeutic interventions, necessitates a comprehensive and multidisciplinary approach. Future research should focus on refining diagnostic algorithms, optimizing surgical techniques, and clarifying the indications for prophylactic resection, thereby enhancing the care and outcomes for patients affected by this condition. The continued evolution of imaging and surgical modalities promises to further elucidate the pathophysiology and management of Meckel's diverticulum, ultimately advancing our understanding and treatment of this complex congenital anomaly.

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