



# Endoscopic approach to Meckel's diverticulum in pediatrics: where has been the focus in the past decade?

Laura Martou<sup>1</sup> · Amulya K. Saxena<sup>1</sup>

Received: 24 September 2023 / Revised: 24 September 2023 / Accepted: 18 October 2023 / Published online: 13 November 2023  
© The Author(s) 2023

## Abstract

**Aim** The aim of this review was to assess the use of laparoscopic techniques in the diagnosis and management of Meckel diverticulum (MD) in pediatric patients in the past decade through relevant literature published from 2013 to 2023.

**Methods** Using PubMed and Embase, articles were identified and selected for application of endoscopic techniques in relation to MD in pediatrics to understand the nuances for this pathology.

**Results** During the past decade a total of 34 studies published were identified and analyzed. The studies highlight the challenges in diagnosing MD and introduce the role of double-balloon enteroscopy (DBE) as a diagnostic tool. Studies comparing outcomes between laparoscopic and open surgical approaches have explored rates of post-operative complications and mortality, with laparoscopy offering the benefit of shorter hospital stays. Focusing on case reports and series, the demographics, morphological features and the presence of complications have shown to significantly influence the choice of surgical approach.

**Conclusions** Endoscopic-related approaches in the past decade have mainly focused on DBE diagnostics and outcomes, whereas few studies have focused on new techniques or endoscopic surgery-related innovative approaches.

**Keywords** Meckel's diverticulum · Laparoscopy · Endoscopy · Pediatric · Review

## Introduction

Meckel's diverticulum (MD) is the most common congenital intestinal malformation with a prevalence of approximately 2% [1]. This blind-ending pouch is located at the antimesenteric border of the ileum and arises from incomplete obliteration of the vitellointestinal duct at around 5 weeks' gestation [2]. With the advent of minimally invasive surgery, laparoscopic techniques have become increasingly sophisticated and consequently have been incorporated in the management of MD in pediatric surgery; however, the efficacy and indications for this remain unclear [3]. Most of the publications related to novel approaches in endoscopic surgery emerged two decades ago, after which a paucity on reporting was noticed as MD was not considered a "hot topic" for reporting. The present review investigates the

reporting of MD in pediatric patients in the past decade on new avenues of application of endoscopy-related technology.

## Methods

A non-systematic review of PubMed and Embase was performed to investigate the use of laparoscopic techniques in diagnosis or treatment of MD in a paediatric population between 2013 and 2023. The key words used were 'Meckel's diverticulum', 'laparoscopic' and 'children', a total of 34 relevant articles were found, 19 and 23 on PubMed and Embase, respectively.

## Results

The breakdown of reports is presented based on the broad areas of investigation and reporting. Four reports describe the use of enteroscopy as a diagnostic tool for MD. One systematic review compared laparoscopic and laparoscopic assisted (LA) resection and 7 studies retrospectively

✉ Laura Martou  
laura.martou18@imperial.ac.uk

<sup>1</sup> Department of Paediatric Surgery, Chelsea and Westminster Hospital NHS Foundation Trust, Imperial College London, 369 Fulham Road, London SW10 9NH, UK

outcomes of laparoscopic intervention for MD in paediatric populations. Fourteen case reports and 8 case series presented and reviewed the use of laparoscopic intervention for MD in children.

### Diagnostic enteroscopy

Conventional tools like gastroscopes and colonoscopes pose inherent challenges in diagnosis of MD due to its location, typically found 45–90 cm proximal to the ileocecal valve [4]. Moreover, the current diagnostic approach utilizing the Tc<sup>99m</sup> Pertechnetate scan, has false negatives and false positives, particularly for patients with severe inflammation, small diverticula, or inverted MD [5, 6]. Alternative diagnostic methods include laparoscopy or double-balloon enteroscopy (DBE).

Geng et al. retrospectively reviewed 42 patients diagnosed with MD using the Tc<sup>99m</sup> Pertechnetate scan; and encountered 6 false negatives, which were confirmed positives both in DBE and exploratory laparoscopy [7]. Similarly He et al. found that DBE diagnosed 86% of their cases confirmed by laparoscopy and suggesting its accuracy in diagnosing MD, with the added benefit of being minimally invasive [8]. Despite this, there are still no well-established sensitivity rates limiting in clinical applicability.

Furthermore, when compared with surgical methods, Zhu et al. found no statistical difference with DBE measurements of the MD site to ileocecal valve [9]. Indicating it can accurately identify bleeding sites and be utilized as an adjunct in surgical planning. Although, transanal DBE was initially described as only being suitable for children weighing > 13 kg, Zhu et al. demonstrated it to be suitable for patients weighing 11.8 and 12.6 kg [9].

Qi et al. reported that laparoscopic surgery was unnecessary in pediatrics due to the thin abdominal wall which allows visualization of the MD with the enteroscopic light [4]. Using DBE, they diagnosed and treated 14 pediatric patients; however, further research is needed to determine its safety and efficacy.

The availability of DBE in emergencies may limit its clinical use, Sato et al. propose using endoscopic retrograde ileography, which is readily available, as an alternate diagnostic technique [10].

### Endoscopic surgical technique

Over the last two decades, the laparoscopic approach for diagnostic confirmation and subsequent resection of MD has become widely adopted in pediatric surgery [11]. This procedure involves a 3-port technique followed by extracorporeal resection through the umbilical wound, which may be extended, to resect and anastomose the MD [12].

Initially described by Attwood et al. single incision laparoscopic surgery (SILS) has emerged reducing the need for multiple incision [13]. The trans-umbilical single-trocar technique uses a 10-mm operating laparoscope with a grasper, followed by delivery of the bowel through the umbilical incision [3]. Case reports illustrate the use of this technique in complex patients with intussusception and ulceration secondary to MD, they reported no intra-operative and post-operative complications [14–16]. Rarely, in cases where the MD is attached to the umbilicus, the trocar may be placed in the suprapubic region as presented by Yang et al [17].

Difficulties with SILS arise when balancing the need for adequate fascial opening and the risk of bleeding, congestion, adhesions and oedema [12]. The availability and cost of specialized instruments may limit the feasibility of such operations. Overcoming this, Mahdi et al. developed a novel cost-effective single port system which was successfully used in 90 procedures, 2 of which were MD [18].

### Outcome analysis

A series of retrospective studies have been performed comparing outcomes of laparoscopic and open resection of MD in children. The studies consistently report comparable rates of post-operative complications and mortality. Ezekian et al. observed a relatively high rate of laparoscopic converted to open (LCO) procedures; nonetheless, this had no impact on mortality or morbidity. [19]. Similar results were found by Duan et al. with the exception of an increase in operative time in the laparoscopic-assisted (LA) cohort [20]. Skertich et al. performed the current largest study of 681 pediatric patients and found the laparoscopic cohort had a shorter length of stay (LOS) and fewer unplanned intubations [21]. Additionally, on univariate analysis they found a lower mortality rate in the laparoscopic and LCO cohort. Although slightly conflicting results, these studies suggest laparoscopic resection of MD has similar outcomes to open procedures with the added cost–benefit of shorter LOS.

Laparoscopic-stapled diverticulectomy (LD) can be performed intracorporeally using Endo GIA staples; an oblique or transverse approach is recommended to prevent the narrowing of the small bowel lumen [22]. This removes the need to enlarge the umbilical incision but requires fine manipulation of the laparoscopic instruments and consequently, highly specialized endoscopic techniques.

Redman et al. performed a systematic review showing a non-statistical decrease in post-operative complications in the LD compared to LA cohort [23]. Their findings, however, all include retrospective studies with small population sizes and variable follow-up periods. LD has the potential to reduce operation time, LOS and risk of adhesive bowel obstruction, however no studies have shown these

to be significantly different. Further research is required to establish the benefits of LD and clear guidelines for which patients would benefit from a LD versus LA surgery.

Lei et al. propose a novel modification of LD by ligating the base of the diverticulum using a similar approach to an appendectomy. They found that basal ligation during a LD significantly reduced operative time compared to the standard LD procedure without the requirement of endo-stapler which reduces the cost of the operation and the need for specialized techniques [24].

An important challenge in this procedure is ensuring complete excision of the heterotopic gastric, or less commonly, pancreatic mucosa which is thought to increase the risk of future complications; histological analysis is, therefore, recommended to ensure adequate clearance [23]. Short and wide MD characteristically contain the ectopic tissue on the tip on the diverticulum; with studies concluding height:diameter ratios less than 1.6 and 2 as a possible cut-offs [25, 26]. Some author suggests palpation of the MD to be necessary to rule out the presence of ectopic tissue, however, others consider it to be misleading and therefore not a limitation of LD [1, 25, 26].

The literature emphasizes the patient's demographics and morphological features of the MD as determinant factors for the choice of surgical procedure and risk of post-operative morbidities. Particularly, surgeons seem to favor open procedures and LA for younger patients [27]. These patients tend to be premature, have increased neurological, cardiac and pulmonary risk factors, a higher ASA classification, and increased risk of physiological perturbations related to CO<sub>2</sub> insufflation [19]. Skertich et al. found the main risk factor for post-operative complications and LCO, to be ASA class and history of cardiac risk, respectively [21]. Open surgery was also the preferred surgical option in cases where: scarred, ulcerated, or gangrenous tissue was present; MD is complicated by a volvulus; and in the presence of basal oedema or an unclear base [1, 20, 22].

Studies suggest SILS is appropriate for diagnosis and resection of MD in neonates and infants [28–30]. This technique minimizes incisions and its associated complications, while yielding good cosmetic results. Masuko et al. illustrate this approach on a 2-day neonate with a perforated MD [30]. Despite the neonatal cavity being narrow, they suggest an umbilical multiuse port allows adequate visibility [30]. Moreover, by eliminating the watch and wait approach, usually taken to avoid the conventional invasive laparotomy, it shortens the fasting time prior to surgery.

### Case report focus

A series of case reports have highlighted the application of laparoscopy in managing intricate complications of MD including torsion and obstruction. 3 cases of axially torsed

MD were identified; in 2 cases a diagnostic laparoscopy followed by an extracorporeal diverticulectomy was performed [31, 32]. In the third case, complicated by gangrene and perforation, resection and anastomoses was performed with SILS [33]. All three patients recovered with no post-operative complications.

In cases of obstruction caused by ingestion of foreign bodies, colonoscopy may not be suitable to locate the foreign body given MD's anatomical position. Alternatively, Cerit et al. performed a fluoroscopy-guided laparoscopy, which effectively located the object, and enable subsequent resection of the MD [34]. In cases of perforation, LD may be a suitable surgical approach; exemplified by case reports detailing intracorporeal LDs on perforated MD resulting from the ingestion of a peanut, button battery and tooth pick [35–37].

## Discussion

Endoscopic-related approaches in the past decade have primarily focused on DBE diagnostics and outcomes with minimal emphasis on new techniques. The evolving landscape of innovative minimally invasive techniques has integrated into clinical practice and emphasized throughout the literature provides a safe and time-effective approach. The choice of surgical procedure, however, must be tailored to the patient's risk factors and morphology of the MD. Similarly, recent literature accentuates a more individualised treatment strategy for incidental MD, advocating for case-specific interventions [38]. This tailored approach coincides with the advancement of laparoscopic techniques, which now enables an alternative approach for MD resection, reflecting a shift towards personalised medicine. However, there is a pressing need for large-scale and randomized control studies to determine the benefit of laparoscopic interventions. These are essential to formulate well-defined guidelines that ensure the safe and optimal utilization of these advancing techniques for pediatric patients with MD.

**Funding** None.

### Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** None as this is a published research analysis.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are

included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

## References

- Fu T, Xu X, Geng L, Huang Y, Ding G, Ji H (2021) The clinical manifestation variety and management choice of Meckel's diverticulum with complication: a single center experience. *Gastroenterol Res Pract* 2021:e6640660
- Sagar J, Kumar V, Shah DK (2006) Meckel's diverticulum: a systematic review. *J R Soc Med* 99:501–505
- Kassem H, Alekrashi M, Elshahat W (2020) Laparoscopy-assisted approach for Meckel's diverticulum in pediatric age. *World J Laparosc Surg* 13:65–68
- Qi S, Huang H, Wei D, Lv C, Yang Y (2015) Diagnosis and minimally invasive surgical treatment of bleeding Meckel's diverticulum in children using double-balloon enteroscopy. *J Pediatr Surg* 50:1610–1612
- Kiratli PO, Aksoy T, Bozkurt MF, Orhan D (2009) Detection of ectopic gastric mucosa using  $^{99m}\text{Tc}$  pertechnetate: review of the literature. *Ann Nucl Med* 23:97–105
- Endo Y, Jimbo K, Arai N, Ochi T, Suzuki M, Yamataka A et al (2022) A pediatric case of inverted Meckel's diverticulum presenting with cyclic vomiting-like symptoms: a case report and literature review. *Children (Basel)* 9:1817
- Geng LL, Chen PY, Wu Q, Li HW, Li DY, Yang M et al (2017) Bleeding Meckel's diverticulum in children: the diagnostic value of double-balloon enteroscopy. *Gastroenterol Res Pract* 2017:7940851
- He Q, Zhang YL, Xiao B, Jiang B, Bai Y, Zhi FC (2013) Double-balloon enteroscopy for diagnosis of Meckel's diverticulum: comparison with operative findings and capsule endoscopy. *Surgery* 153:549–554. <https://doi.org/10.1016/j.surg.2012.09.012>
- Zhu Z, Zhou S, Cai H, Zhao H, Wang Z (2012) The diagnostic and treatment values of double-balloon enteroscopy in children's Meckel's diverticular bleeding. *Medicine (Baltimore)* 100:e24823
- Sato T, Tagawa M, Wada H, Sumazaki R (2018) Diagnosis of Meckel diverticulum on endoscopic retrograde ileography in a child. *Pediatr Int* 60:481–482. <https://doi.org/10.1111/ped.13530>
- Bertozzi M, Melissa B, Magrini E, Di Cara G, Esposito S, Apignani A (2017) Obstructive internal hernia caused by mesodiverticular bands in children: two case reports and a review of the literature. *Medicine* 96:e8313
- Tam YH, Chan KW, Wong YS, Houben CH, Pang KK, Tsui SY, Mou JW, Lee KH (2013) Single-incision laparoscopic surgery in diagnosis and treatment for gastrointestinal bleeding of obscure origin in children. *Surg Laparosc Endosc Percutan Tech* 23:e106–e108. <https://doi.org/10.1097/SLE.0b013e3182806517>
- Attwood SE, McGrath J, Hill AD, Stephens RB (1992) Laparoscopic approach to Meckel's diverticulectomy. *Br J Surg* 79:211. <https://doi.org/10.1002/bjs.1800790306>
- Vasconcelos-Castro S, Fernandes S, Soares-Oliveira M (2020) Single-instrument thoracic and abdominal surgery in children: minimizing minimally invasive surgery. *J Laparoendosc Adv Surg Tech A* 30:1127–1130. <https://doi.org/10.1089/lap.2020.0329>
- Lima M, Gargano T, Maffi M (2013) An unusual case of intramural Meckel's diverticulum as a lead point for ileoileal intussusception—laparoscopically assisted management. *J Pediatr Surg Case Rep* 1:111–113
- Dames EL, Hamouda ESM (2015) Radiologic imaging in Meckel diverticulum complications. *J Medical Ultrasound* 23:133–141
- Yang T, Zou Y, Li J, Yang J, Tan T, Pan J et al (2015) Laparoscopic excision of an atypical Meckel's diverticulum. *J Pediatr Surg Case Rep* 30:32–33
- Mahdi BD, Rahma C, Mohamed J, Riadh M (2015) Single-port laparoscopic surgery in children: a new alternative in developing countries. *Afr J Paediatr Surg* 12:122–125
- Ezekian B, Leraas HJ, Englum BR, Gilmore BF, Reed C, Fitzgerald TN et al (2019) Outcomes of laparoscopic resection of Meckel's diverticulum are equivalent to open laparotomy. *J Pediatr Surg* 54:507–510
- Duan X, Ye G, Bian H, Yang J, Zheng K, Liang C et al (2015) Laparoscopic vs. laparoscopically assisted management of Meckel's diverticulum in children. *Int J Clin Exp Med* 8:94–100
- Skertich NJ, Ingram MC, Grunvald MW, Williams MD, Ritz E, Shah AN et al (2011) Outcomes of laparoscopic versus open resection of Meckel's diverticulum. *J Surg Res* 264:362–367
- Alemayehu H, Stringel G, Lo IJ, Golden J, Pandya S, McBride W et al (2014) Laparoscopy and complicated Meckel diverticulum in children. *JSLs*. <https://doi.org/10.4293/JSLs.2014.00015>
- Redman EP, Mishra PR, Stringer MD (2020) Laparoscopic diverticulectomy or laparoscopic-assisted resection of symptomatic Meckel diverticulum in children? A systematic review. *Pediatr Surg Int* 36:869–874
- Lei J, Xu W, Yang W, Xiao J, Huang H, Deng Q et al (2018) A faster and simpler way of operation for Meckel's diverticulum: basal ligation combined with intraoperative frozen section. *Surg Endosc* 32:1464–1469
- Papparella A, Nino F, Noviello C, Marte A, Parmeggiani P, Martino A et al (2014) Laparoscopic approach to Meckel's diverticulum. *World J Gastroenterol* 20:8173–8178
- Gezer HÖ, Temiz A, İnce E, Ezer SS, Hasbay B, Hiçsönmez A (2016) Meckel diverticulum in children: evaluation of macroscopic appearance for guidance in subsequent surgery. *J Pediatr Surg* 51:1177–1180
- Kumar R, Srivastava V, Pandey V (2020) Symptomatic and incidental Meckel's diverticulum in children: our experience and Lesson. *JCDR* 14:20–22
- Wu KL, Tsai HL, Liu Z, Li SK, Huang CF (2020) A walled-off ruptured Meckel's diverticulum in an infant. *Pediatr Int* 62:874–875
- Koetter P, Cochran E, Tsai AY (2021) Mesenteric Meckel's diverticulum in a 17 month old female. *J Pediatr Surg Case Rep* 69:101835
- Masuko T, Tanaka Y, Kawashima H, Amano H (2016) Diagnostic laparoscopy for neonatal perforated Meckel's diverticulum. *J Minim Access Surg* 12:71–72
- Tassinari D, Cimatti AG, Tani G, Lima M (2013) A common case of gastroenteritis in a child followed by an axial torsion of Meckel diverticulum: a rare and unusual complication. *BMJ Case Rep*. <https://doi.org/10.1136/bcr-2012-006656>
- Ahmed K, Hayet Z, Hamdi L, Mahdi BD, Mohamed J, Riadh M (2016) Laparoscopic management of an axially torsed gangrenous Meckel's diverticulum in a child. *Afr J Pediatr Surg* 13:150
- Ahmed K, Hayet Z, Hamdi L, Mahdi BD, Mohamed J, Riadh M (2016) Laparoscopic management of an axially torsed gangrenous Meckel's diverticulum in a child. *Afr J Paediatr Surg* 13:150–151
- Cerit K, Kalyoncu A, Erbarut I, Kiyani G, Dagli T (2017) Laparoscopic approach to a coin trapped in Meckel's diverticulum. *Ulus Travma Acil Cerrahi Derg* 23:438–440
- Su CH, Lee JY, Chang YT (2013) Perforation of Meckel's diverticulum by a peanut presenting as a mesentery abscess. *Iran J Pediatr* 23:223–225
- Kadhi A, Crankson S, Al Jadaan S (2020) Meckel's diverticulum perforation by a wooden toothpick in a child: a case report. *J Pediatr Surg Case Rep* 52:101322

37. Elmalik K, Patel RV, Gabra H (2013) Laparoscopic management of intestinal obstruction and perforation of Meckel's diverticulum by a button battery. *J Pediatr Surg Case Rep* 1:17–19
38. Lindeman R-J, Søreide K (2020) The many faces of Meckel's diverticulum: update on management in incidental and symptomatic patients. *Curr Gastroenterol Rep* 22:3. <https://doi.org/10.1007/s11894-019-0742-1>