Perforated Meckel’s diverticulum in neonates: a report of six cases and systematic review of the literature

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Abstract
Background: Perforation of Meckel Diverticulum (MD) is a rare cause of pneumoperitoneum in neonates. We hereby report six cases of perforation of MD in neonates, with addition of 53 cases from systematic review of the literature. A systematic review was performed using Mesh terms "Neonate, Meckel Diverticulum, Perforation, Pneumoperitoneum." All reports of perforated MD in the English literature were identified. Details of our 6 cases were analyzed in similar fashion.

Results: A total of 3027 manuscripts were screened and 59 cases including 6 of our own were identified. The vast majority (78%) were female. Fifty patients (84.7%) presented in the newborn period. Half of the cases (52.5%) had associated anomalies and 13 neonates (22%) required oxygen supplementation including CPAP or ventilatory support before surgery. In 73% of the cases, a resection of gut was undertaken. Histopathological assessment in 44 cases (74.6%) revealed no ectopic gastric mucosa. Three cases demised prior to treatment. The outcome in the vast majority was excellent with 84.7% surviving and discharged well.

Conclusion: Perforated MD is an unusual cause of a pneumoperitoneum in the newborns. Diagnosis is established at laparotomy and it rare to find ectopic mucosa histopathologically. The overall outcome is excellent.

Keywords: Neonate, Meckel diverticulum, Neonatal, Pneumoperitoneum

Introduction
Pneumoperitoneum is a serious condition in neonates requiring immediate surgical intervention. The most common causes in this age group are necrotizing enterocolitis and intestinal atresia including a host of idiopathic pathologies. A rare cause is a perforated Meckel diverticulum (MD), of which, only a limited number of cases have been reported to date [1–3].

Authors encountered few cases of perforated MD and it intrigued us to look into the literature. We had many unanswered questions, which we intended to answer. These include

1. As commonly said that MD is two times more common in males than females, does this rule also apply in neonates having perforated MD.
2. What may be the cause of perforation of MD.? Is it hypertrophied gastric mucosa?
3. What is the outcome in terms of survival of these neonates?
4. Do these neonates present late in neonatal life? If so, then some environmental factor may be involved and must be investigated.
5. Is there any particular pattern of presentations of perforated MD which may help us diagnose these patients early?
6. What may the risk factors for mortality in these patients?
In this systematic review, we intended to look for the presentation details and outcomes of the newborns with MD and tried to answer these questions. Here, we report six cases of perforated MD in neonates and their details are being summarized in Table 1.

Methodology
We conducted this systematic review with the aim to get all reports from the literature about MD perforation in neonates. We used PRISMA checklist to maintain the integrity and structure. It was performed using Mesh terms “Neonate, Meckel Diverticulum, Perforation, Pneumoperitoneum.” Three databases were accessed: PubMed, Google Scholar, and Cochrane. No filter for the time, language, or region was applied during the literature search, and all data to date (May 2021) was retrieved. We included all reports/studies reporting perforated MD in neonates. Two authors (NL and MA), acting independently, identified full-text reports which were then collated. Included were all reports of perforation of MD, irrespective of the outcome. Further, reference lists of all those full texts were seen to identify any missing reports, and if found, it was included. Also, we went through the literature review table of these manuscripts to find any missing reports. Neonate was defined as any child within 30 days of life at the time of presentation. The following information was extracted from the reports: author, journal, year of publication, gestational age in weeks, gender, age at the time of presentation, the weight of the child at the time of presentation, associated anomaly, treatment strategy, histopathology report, in particular whether ectopic tissue was found, pre-operative history of ventilation, and outcome. Details of our own cases were similarly recorded on an Excel spreadsheet and analyzed. Along with simple descriptive statistics, we also conducted logistic regression analysis to look for the odd’s ratio (OR) for mortality among these factors in order to identify the risk factors.

Results
A total of 3027 manuscripts were screened and 62 cases were identified. Nine cases were excluded as the manuscripts were published in languages other than English [52–60]. A total of 59 cases, including our own six cases, were finally included in the study (Table 1). The details of all the cases are summarized in Tables 1 and 2.

Twenty-three patients (39%) were born prematurely, and the majority of patients (79.7%) were male. Fifty patients (84.7%) presented in the newborn period. Almost half of the cases (52.5%) reported other congenital anomalies. These anomalies included Omphalocele, anorectal malformation, Hirschsprung’s disease, meconium ileus, and many more (Table 1). Mothers of 11 neonates had some complications during gestation, including, bronchial asthma, UTI, Diabetes, PIH, HELLP syndrome, and abruptio placenta. Thirteen neonates (22%) required oxygen supplementation including CPAP or ventilatory support before surgery. Preoperative imaging rarely gives a clue as to the cause of the pneumoperitoneum. Only one case was suspected preoperatively and the rest diagnosed at laparotomy. In 73% of the cases, surgeons opted to resect the involved segment and restore the continuity of the gut. Histopathological assessment in 44 cases (74.6%) revealed no ectopic gastric mucosa. Three cases were diagnosed on autopsy as patients died before any treatment. The outcome in the vast majority was excellent with 84.7% of cases discharged well. Composite data are summarized in Table 2. Logistic regression showed that none of the factors were significantly associated with the mortality among these patients (Table 3).

Discussion
MD is a remnant of the omphalomesenteric duct, which normally regresses during the 5th–7th week of gestation. Its typically a 3–6-cm-long outpouching on the antimesenteric border, 50–75 cm from the ileo-caecal junction and usually contains all four intestine layers. In 30 to 50% of patients, it contains ectopic tissues which maybe gastric, pancreatic, colonic, duodenal, or endometrial. Despite being the most common congenital anomaly of the gastrointestinal tract, symptomatic manifestation in the neonatal period is rare. Complications may occur in up to 4% of cases, and in the symptomatic, intestinal perforation is seen fewer than 10% of cases [1]. Diverticular length and base diameter are well-known predisposing factors to complications with long, narrow-based diverticula thought to predispose to obstruction on the basis of intussusception and inflammation [3, 5, 7]. Common manifestations of neonatal MD include perforation, intussusception, segmental ileal dilatation, and ileal volvulus [8, 28, 61]. Bertozzi and colleagues [15] identified bowel obstruction (58.3%) and pneumoperitoneum (33.3%) as the most common clinical manifestations. Umbilical catheterization is a rare cause of iatrogenic perforation [61].

Typically, MD is synonymous with the rule of 2; seen in 2% of the population, twice as frequent in the male sex with two percent being symptomatic [15]. Our collective review of perforated cases found a significant male predominance with a ratio of 51 to 8. This trend is interesting and has not previously been identified and further study to explain this phenomenon is required.

The timing of presentation is also of interest as 84.7% of patients in this review presented within the first week of life. Some presented immediately after birth suggesting a peri or very early post-natal onset of pathology [23,
| Sr. no. | Year | Gender (age) | Gestational age (weeks) | Age at presentation (days) | Weight (g) | Ectopic tissue (histopathology) | Management | Outcome | Associated anomalies | Pre-op ventilation |
|--------|------|--------------|-------------------------|---------------------------|-----------|---------------------------------|------------|---------|---------------------|--------------------|
| 1      | Case 1 | 37 | M | 3 | 3000 | None | ETEA | Dis | None | No |
| 2      | Case 2 | 36 | M | 2 | 2800 | None | ETEA | Dis | None | No |
| 3      | Case 3 | 37 | M | 2 | 2500 | None | ETEA | Expired | Anorectal Malformation | No |
| 4      | Case 4 | NR | M | 5 | 2650 | None | ETEA | Dis | None | No |
| 5      | Case 5 | 37 | M | 4 | NR | None | ETEA | Dis | None | No |
| 6      | Case 6 | 37 | M | 3 | NR | None | ETEA | Dis | Omphalocoele minor | No |
| 7      | Bindi [4] | 2020 | NR | M | 3 | NR | NR | ETEA | Dis | COVID-19 | No |
| 8      | Charki [5] | 2019 | 37 | M | 1 | 3500 | None | ETEA | Dis | Omphalocoele minor | No |
| 9      | Wang [3] | 2019 | 27 | M | 2 | 1370 | None | ETEA | Dis | None | Yes |
| 10     | McKelvie [2] | 2019 | 30 | F | 3 | 1120 | None | ETEA | Dis | Cord prolapse | Yes |
| 11     | Oelaru [6] | 2018 | 31 | M | 3 | 1900 | None | ETEA | Dis | Product of IVF, twin pregnancy | Yes |
| 12     | Nhatrang [7] | 2018 | 23 | M | 5 | 625 | None | Ileostomy | Dis | None | Yes |
| 13     | Louati [8] | 2017 | 37 | M | NR | 2350 | None | ETEA | Dis | None | No |
| 14     | Jin [9] | 2017 | 37 | F | 1 | 2350 | None | ETEA | Dis | Omphalocoele, VSD, ASD | No |
| 15     | Ayari [10] | 2016 | 28 | M | 1 | 1400 | NR | ETEA | Dis | Chorioamnionitis | No |
| 16     | Ayari [10] | 2016 | 26 | M | 7 | 750 | NR | Ileostomy | Dis | Hyaline membrane disease | Yes |
| 17     | Masuko [1] | 2016 | 34 | M | 2 | 1970 | None | ETEA | Dis | None | Yes |
| 18     | Frooghi [11] | 2016 | 37 | M | 3 | 3200 | Gastric tissue | ETEA | Dis | None | No |
| 19     | Alvares [12] | 2015 | 30 | M | 10 | 940 | None | ETEA | Dis | Hyaline membrane disease | Yes |
| 20     | Borgi [13] | 2014 | 29 | M | 1 | 1400 | None | ETEA | Dis | Twin pregnancy, other twin dies | Yes |
| 21     | Smolkin [14] | 2013 | 28 | M | 4 | 1200 | None | ETEA | NR | PDA | Yes |
| 22     | Bertozzi [15] | 2013 | 34 | M | 5 | 2500 | None | Ileostomy | Dis | Mother—bilateral hydronephrosis | No |
| 23     | Crankson [16] | 2013 | 29 | M | 1 | 1640 | None | ETEA | Dis | Abruptio placenta | No |
| 24     | Skelly [17] | 2012 | 39 | M | 2 | 3280 | None | ETEA | Dis | Infantile hypertrophic pyloric stenosis, skip segment HD | No |
| 25     | Qasim [18] | 2012 | 37 | M | 7 | 2500 | NR | ETEA | Death | None | No |
| 26     | Lee DS [19] | 2012 | 37 | M | 1 | 2510 | None | ETEA | Dis | None | No |
| 27     | Khan [20] | 2012 | 29 | F | 6 | 650 | None | ETEA | Dis | IGR, PDA, on inotropic support | Yes |
| 28     | Kampfen [21] | 2011 | 37 | F | 18 | 4000 | NR | ETEA | Dis | None | No |
| 29     | Anay [22] | 2011 | 24 | M | 3 | 740 | None | Ileostomy | Dis | Mother—PIH, DM (on Metformin) | Yes |
| Sr. no. | Year | Gestational age (weeks) | Gender | Age at presentation (days) | Weight (g) | Ectopic tissue (histopathology) | Management | Outcome | Associated anomalies | Pre-op ventilation |
|---------|------|-------------------------|--------|---------------------------|------------|-------------------------------|-----------|---------|----------------------|------------------|
| 30      | Nakazawa [23] | 2009 | 36 | M | 1 | 1776 | None | Ileostomy | Dis | IUGR | No |
| 31      | Alkan [24] | 2009 | 38 | F | 1 | 2800 | None | ETEA | Dis | None | No |
| 32      | Aguayo [25] | 2009 | 28 | M | 6 | 810 | None | Ileostomy | Dis | None | No |
| 33      | Mavridis [26] | 2008 | 37 | M | 1 | 3800 | None | ETEA | Dis | Omphalocoele minor | No |
| 34      | Oyachi [27] | 2007 | 37 | M | 17 | 3060 | None | ETEA | Dis | None | No |
| 35      | Sy [28] | 2006 | 40 | F | 3 | 3200 | None | ETEA | Dis | Hirschsprung’s disease—mid transverse colon | No |
| 36      | Chang [29] | 2006 | 33 | M | 2 | 2040 | None | ETEA | Dis | None | No |
| 37      | Lim [30] | 2005 | 39 | M | 9 | 3540 | None | ETEA | Dis | None | No |
| 38      | Ojha [31] | 2004 | 37 | M | 6 | 3000 | None | ETEA | Dis | Segmental dilatation of ileum | No |
| 39      | Zahra [32] | 2003 | 37 | M | 3 | 2070 | None | NR | Dis | Mother—bronchial asthma, UTI | No |
| 40      | Okazaki [33] | 2003 | 39 | M | 3 | 2698 | None | NR | Dis | Mother—hyperthyroid (took methimazole). Child—needed anti-thyroid drugs for 10 days | No |
| 41      | Tekant [34] | 2001 | 30 | M | 3 | 2600 | Gastric mucosa | ETEA | Dis | Mother had high gastrin levels and positive H. Pylori | No |
| 42      | Kumar [35] | 1998 | NR | M | 5 | 2300 | None | ETEA | Dis | None | No |
| 43      | Gandy [36] | 1997 | 37 | M | 8 | 4500 | None | NR | Dis | Diabetic mother | No |
| 44      | Yeh [37] | 1996 | NR | M | 8 | NR | None | ETEA | Dis | None | No |
| 45      | Ford [38] | 1992 | 37 | NR | 1 | 1900 | Pancreatic tissue | Ileostomy | Death | VATER, vertebral anom, imperforate anus, tracheoesophageal fistula, absent right kidney, dysplastic left kidney, single umbilical artery, oligohydramnios | Yes |
| 46      | Coppes [39] | 1991 | 32 | M | 3 | 1780 | None | ETEA | Dis | None | Yes |
| 47      | Khope [40] | 1988 | 37 | M | 3 | NR | Gastric Mucosa | ETEA | Dis | Undescended testis | No |
| 48      | Wright and Bhawandeen [41] | 1986 | 37 | M | 1 | 3515 | Both gastric and pancreatic | ETEA | Dis | Hydrocoele | No |
| 49      | Dalens [42] | 1981 | 40 | M | 2 | 3650 | Gastric | NR | Dis | None | No |
| 50      | Mcmanus [43] | 1980 | NR | M | 1 | 2268 | None | ETEA | Dis | None | No |
### Table 1 (continued)

| Sr. no. | Year | Gestational age (weeks) | Gender | Age at presentation (days) | Weight (g) | Ectopic tissue (histopathology) | Management | Outcome | Associated anomalies | Pre-op ventilation |
|---------|------|-------------------------|--------|---------------------------|------------|--------------------------------|------------|---------|---------------------|-------------------|
| 51      | Lin  [44] | 1978 | 36 | M | 4 | 2450 | None | ETEA | Dis | None | No |
| 52      | De Oliveira [45] | 1967 | NR | NR | 7 | NR | NR | ETEA | Dis | None | No |
| 53      | Mestel [46] | 1966 | NR | NR | NR | NR | NR | Dis | None | No |
| 54      | Mestel [46] | 1966 | NR | NR | NR | NR | NR | Dis | None | No |
| 55      | Roger [47] | 1964 | NR | M | 1 | 2300 | None | ETEA | Dis | None | No |
| 56      | Abramson [48] | 1960 | NR | F | 5 | 3742 | None | ETEA | Dis | None | No |
| 57      | Gilbert [49] | 1958 | 34 | M | 1 | 2693 | None | Autopsy | Death | Cord twisted around neck | No |
| 58      | Rosza and Gross [50] | 1953 | 32 | F | 1 | NR | None | Autopsy | Death | Meconeum ileus | No |
| 59      | Hunter [51] | 1928 | NR | M | 4 | NR | None | Died | Death | None | No |

*M* male,  *F* female,  *ETEA* end to end anastomosis,  *Dis* discharged,  *NR* not reported,  *VSD* ventricular septal defect,  *ASD* atrial septal defect,  *HD* Hirschsprung’s disease,  *PDA* patent ductus arteriosus,  *IUGR* intra-uterine growth retardation,  *DM* diabetes mellitus
26, 45]. There is no evidence to suggest that the perforations occur antenatally and it would be rare for this to be detected as expectant mothers are not routinely subjected to ultrasound screening in the last days of pregnancy. Gilbert et al., reported a neonate who died before any intervention and suspected the perforation to be antenatal [49].

The etiology of perforated MD is elusive, and many theories have been put forth. In older children and adults, ulceration induced perforation secondary to gastric ectopic tissue within a MD is well recognized. Only 6.8% (n = 4) of cases in this study had documented gastric tissue within the MD suggesting that other factors are responsible [27]. Tekant et al. proposed H. Pylori infection as a possibility [34]. Some have postulated, but without much support, that this may be secondary to the separation of vitelline remnants from the abdominal wall [6]. Oyachi et al. proposed a knotting of a long MD around itself, leading to weakness in the intestine walls ultimately leading to perforation [27]. We however did not see evidence of this in our cases as the perforations were discreet and at the tip of the MD with no proximal obstruction.

A tenable hypothesis is diverticulitis within the pouch resulting in erosion of the wall with resultant perforation. In this review, although no ectopic mucosa was found (n = 44), inflammation was noted supporting the inflammatory hypothesis as a reasonable cause for the perforation. Although presentation is within the first week of life it is likely that the trigger for the inflammatory process occurs in the perinatal period with gradually progression. Notwithstanding this, a single case has been reported where abdominal distension with ventilatory support was required at birth and later surgery confirming a perforated MD [13].

Perforation of the appendix proximal to distal Hirschsprung’s disease is well documented. Skelly reported a case where the child had skip segment Hirschsprung’s disease, and a perforated MD [17].

The standard presentation for perforated MD is a clinically acute abdomen with X ray confirmation of free intra-abdominal air. Rarely, unusual manifestations such as a scrotal pneumatocele secondary a perforated MD are seen [39]. It is exceptional for a specific diagnosis to be made preoperatively and a definite diagnosis of MD is usually established on laparotomy. However, Ojha et al. reported a case of a neonate where a pre-operative abdominal X-ray showed a massively dilated gut loop with outpouching which raised the possibility of a perforated MD [31].

With respect to management, most surgeons, 72.9% (n = 43), opted for resection along with end-to-end anastomosis. However, in some cases, 10.2% (n = 6), due to

### Table 2

| Gestational age (weeks) | Cases | Percentage |
|-------------------------|-------|------------|
| < 37 weeks              | 23    | 39%        |
| ≥ 37 weeks              | 25    | 42.4%      |
| NR                      | 11    | 18.6%      |

| Gender                  | Cases | Percentage |
|-------------------------|-------|------------|
| Male                    | 47    | 79.7%      |
| Female                  | 8     | 13.6%      |
| NR                      | 4     | 6.8%       |

| Age at presentation     | Cases | Percentage |
|-------------------------|-------|------------|
| ≤ 7 days                | 50    | 84.74%     |
| > 7 days                | 6     | 10.16%     |
| NR                      | 3     | 5.1%       |

| Weight                  | Cases | Percentage |
|-------------------------|-------|------------|
| < 2500 g                | 25    | 2.4%       |
| ≥ 2500 g                | 24    | 40.7%      |
| NR                      | 10    | 16.94%     |

| Ectopic mucosa on histopathology | Cases | Percentage |
|----------------------------------|-------|------------|
| Gastric                          | 4     | 6.8%       |
| Pancreatic                       | 1     | 1.7%       |
| Both gastric and pancreatic      | 1     | 1.7%       |
| No ectopic mucosa                | 44    | 74.6%      |
| NR                               | 9     | 15.2%      |

| Management                      | Cases | Percentage |
|---------------------------------|-------|------------|
| Resection and anastomosis       | 43    | 72.9%      |
| Stoma formation                 | 7     | 11.9%      |
| NR                              | 6     | 10.2%      |
| Autopsy                         | 3     | 5.1%       |

| Outcome                         | Cases | Percentage |
|---------------------------------|-------|------------|
| Death                           | 7     | 11.9%      |
| Discharge                       | 51    | 84.7%      |
| NR                              | 1     | 1.7%       |

| Associated anomalies            | Cases | Percentage |
|---------------------------------|-------|------------|
| Yes                             | 31    | 52.54%     |
| No                              | 28    | 47.45%     |

| Pre-operative ventilation       | Cases | Percentage |
|---------------------------------|-------|------------|
| Yes                             | 13    | 22%        |
| No                              | 46    | 78%        |

### Table 3

| Factors                              | OR: 95%CI (range): P value |
|--------------------------------------|----------------------------|
| Pre-operative ventilation            | 0.556: (0.061–5.080): 0.603 |
| Male gender                          | 0.651: (0.063–6.708): 0.718 |
| Presence of any ectopic mucosa       | 1.567: (0.156–15.768): 0.703 |
| Presence of associated anomaly       | 1.235: (0.251–7.071): 0.795 |
| Low birth weight (weight less than 2500 g) | 0.292: (0.028–3.021): 0.302 |
| Prematurity (gestational age less than 37 weeks) | 0.698: (0.106–4.607): 0.709 |

The etiology of perforated MD is elusive, and many theories have been put forth. In older children and adults, ulceration induced perforation secondary to gastric ectopic tissue within a MD is well recognized. Only 6.8% (n = 4) of cases in this study had documented gastric tissue within the MD suggesting that other factors are responsible [27]. Tekant et al. proposed H. Pylori infection as a possibility [34]. Some have postulated, but without much support, that this may be secondary to the separation of vitelline remnants from the abdominal wall [6]. Oyachi et al. proposed a knotting of a long MD around itself, leading to weakness in the intestine walls ultimately leading to perforation [27]. We however did not see evidence of this in our cases as the perforations were discreet and at the tip of the MD with no proximal obstruction.

A tenable hypothesis is diverticulitis within the pouch resulting in erosion of the wall with resultant perforation. In this review, although no ectopic mucosa was found (n = 44), inflammation was noted supporting the inflammatory hypothesis as a reasonable cause for the perforation. Although presentation is within the first week of life it is likely that the trigger for the inflammatory process occurs in the perinatal period with gradually progression. Notwithstanding this, a single case has been reported where abdominal distension with ventilatory support was required at birth and later surgery confirming a perforated MD [13].

Perforation of the appendix proximal to distal Hirschsprung’s disease is well documented. Skelly reported a case where the child had skip segment Hirschsprung’s disease, and a perforated MD [17].

The standard presentation for perforated MD is a clinically acute abdomen with X ray confirmation of free intra-abdominal air. Rarely, unusual manifestations such as a scrotal pneumatocele secondary a perforated MD are seen [39]. It is exceptional for a specific diagnosis to be made preoperatively and a definite diagnosis of MD is usually established on laparotomy. However, Ojha et al. reported a case of a neonate where a pre-operative abdominal X-ray showed a massively dilated gut loop with outpouching which raised the possibility of a perforated MD [31].

With respect to management, most surgeons, 72.9% (n = 43), opted for resection along with end-to-end anastomosis. However, in some cases, 10.2% (n = 6), due to
In summary we found following answers:

1. Question: As commonly said that MD is two times more common in males than females, does this rule also apply in neonates having perforated MD?
   Answer: No, this rule does not apply in this cohort of patients. Male preponderance is much more (6.3:1).

2. Question: What may be the cause of perforation of MD. Is it gastric mucosa?
   Answer: Gastric mucosa is found in only 8.5% of cases. So, the cause remains largely unknown.

3. Question: What is the outcome in terms of survival of these neonates?
   Answer: Generally, these neonates have a good survival as other surgical conditions of this age group.

4. Question: Do these neonates present late in neonatal life? If so, then some environmental factor may be involved and must be investigated.
   Answer: Most of these patients present in early neonatal age, so we don’t presume the involvement of some environmental agents; however, the possibility can’t be ruled out.

5. Question: Is there any particular pattern of presentations of perforated MD which may help us diagnose these patients early?
   Answer: No, we did not find any particular pattern and generally it was non-specific presentation with intestinal obstruction.

6. What may the risk factors for mortality in these patients?
   Answer: We did not find any factor being significantly associated with the mortality.

References

1. Masuko T, Tanaka Y, Kawashima H, Amano H. Diagnostic laparoscopy for neonatal perforated Meckel's diverticulum. J Minim Access Surg. 2016;12(1):71–2. https://doi.org/10.4103/0972-9941.158150.

2. McKelvie M, Soares-Oliveira M, Wang-Koh Y, Trayers C, Aslam A. Beware the innocent presentation of a spontaneous perforated Meckel Diverticulum: A rare case and review of the literature. Pediatr Emerg Care. 2019;35(12):881–3. https://doi.org/10.1097/pec.0000000000001993.

3. Wang YJ, Wang T, Xia SL, Zhang YC, Chen WB, Li B. Perforation of Meckel's diverticulum: A very low birth weight neonate with severe pneumoperitoneum and review of literature. Turk J Pediatr. 2019;61(3):460–5. https://doi.org/10.24953/turkped.2019.03.025.

4. Bindi E, Crucetti A, Ileri M, Mariscoli F, Carnielli VP, Simonini A, et al. Meckel's diverticulum perforation in a newborn positive to Sars-Cov-2. J Pediatr Surg Case Rep. 2020;62:101641. https://doi.org/10.1016/j.pscr.2020.101641.

5. Chariki MT, Abdelaloufi H, Andaloussi S, Oukhouya MA, Mahmoudi A, El Madi A, et al. Congenital fistulisation of Meckel's diverticulum in omphalocele sac: case report. Pan Afr Med J. 2019;32:20. https://doi.org/10.11604/pamj.2019.32.20.15010.

6. Orelaru FO, Reddy NS, Brahmandam P. Perforated Meckel's diverticulum in a neonate. J Pediatr Surg Case Rep. 2018;37:37–40.

7. Le N, Alemayehu H, Singh V, Hendrickson RJ. Pneumoperitoneum in a micro–preemie due to perforated Meckel's diverticulum. J Neonatal Surg. 2018;7(1):16. https://doi.org/10.21699/jns.v7i1.670.

8. Louati H, Zouari N, Jallouli M, Dhacou MB, Zitouni H, Hmni R. Perforated Meckel's Diverticulum causing intussusception in a neonate. J Neonatal Surg. 2017;6(3):73. https://doi.org/10.21699/jns.v6i3.568.

9. Jin H, Han J-W, Oh C, Kim H-Y, Jung S-E. Perforated Meckel's diverticulum in omphalocele. J Pediatr Surg Case Rep. 2017;17:28–30.
59. Daum R, Hollmann G. Fetal perforation of Meckel’s diverticulum as a cause of newborn infant ileus. Zentralbl Chir. 1967;92(3):107–9.
60. Garrido F, Sanchez A, Rubio F, Hernandez A, Quintero S, Bernal C, et al. Intestinal perforation as the first sign of Meckel’s diverticulum in the neonatal period. Rev Esp Pediatr. 1997;53:561–4.
61. Costa S, De Carolis MP, Savarese I, Manzoni C, Lacerenza S, Romagnoli C. An unusual complication of umbilical catheterisation. Eur J Pediatr. 2008;167(12):1467–9. https://doi.org/10.1007/s00431-008-0691-4.

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