Multidetector-row computed tomography (MDCT) features of small bowel obstruction (SBO) caused by Meckel’s diverticulum

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KEYWORDS
Meckel’s diverticulum; Multidetector computed tomography; Intestinal obstruction; Small intestine; Intussusception

Abstract
Objectives: To report the multidetector-row computed tomography (MDCT) findings of small bowel obstruction (SBO) caused by Meckel’s diverticulum.

Materials and methods: Ten patients (9 men and 1 woman; age range, 2–44 years; median age, 21 years) with surgical proven Meckel’s diverticulum who presented SBO on the preoperative MDCT were included in the study.

Results: On MDCT, all patients presented with SBO, either high-grade (n = 6) or low-grade obstruction (n = 4). Meckel’s diverticulum was identified in five patients (n = 5, 50%) on preoperative MDCT. In the five patients in whom a diverticulum was not seen on preoperative MDCT, MDCT showed a transition site on ileum with dilated proximal loops (n = 3), pneumoperitoneum (n = 1), jejuno-jejunal intussusception (n = 1). Transition zone was located near midline in four patients (4/5, 80%).

Conclusion: The diagnosis of Meckel’s diverticulum complicated SBO can be made with certainty when the diverticulum is visualized on preoperative MDCT. However, the preoperative diagnosis is difficult if the Meckel’s diverticulum is not noted on the MDCT. When the obstructive processes are visualized in the lower abdomen or pelvis, particularly near the midline, one should keep in mind that SBO may be caused by Meckel’s diverticulum without prior surgical history.

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Meckel’s diverticulum is a congenital anomaly of the gastrointestinal system attributable to incomplete obliteration of the omphalomesenteric duct. Meckel’s diverticulum has an incidence of 1–2% in the general population, and most of the diverticula remain asymptomatic. The lifetime complication rate of Meckel’s diverticulum is approximately 4% and includes symptomatic complications such as bleeding, obstruction, and inflammation [1–3]. On computed tomography (CT), Meckel’s diverticulum may appear as a fluid- or air-filled blind-ending pouch that arises from the antimesenteric side of the distal ileum. However, CT has low sensitivity for the detection of uncomplicated Meckel’s diverticulum because its appearance mimics that of a normal bowel loop. Complicated Meckel’s diverticulum represents an important cause of acute abdominal pain [3,4], and most cases with inflamed Meckel’s diverticulum may be visualized on CT. However, diagnosis of secondary intestinal obstruction caused by Meckel’s diverticulum is most difficult [5].

The purpose of this study was to describe the MDCT features of SBO caused by Meckel’s diverticulum in 10 patients who were evaluated by MDCT before undergoing surgery.

Materials and methods

This study was approved by the hospital’s Institutional Review Board, and the requirement of informed consent was waived for this retrospective study.

Patient groups

Based on a review of medical records for the time period from January 2006 to December 2014, 43 patients with Meckel’s diverticulum were searched, and among them, 17 patients were pathologically confirmed. The seven patients are excluded from final enrollment because four patients were discovered during surgery for another primary reason (such as traumatic small bowel perforation, adhesive ileus, appendectomy, and sigmoid volvulus) and three patients showed no small bowel obstruction on CT. The remaining 26 patients were excluded because they did not pathologically confirmed (three had intestinal bleeding, and others had suspected Meckel’s diverticulitis on CT, with relevant clinical features, but received only symptomatic treatment and observation).

Ten patients (median age 21; range, 2–44 years) included in our final analysis had surgically-proven disease, and SBO on abdominal CT scan. All patients who had undergone preoperative MDCT had subsequent surgically confirmed Meckel’s diverticulum-related complications.

MDCT technique

Because CT examinations had been performed with various types of equipment over a long period, the scanner techniques and protocols varied. Two patients underwent CT scanning at a referring hospital.

The CT examinations were performed using all variable channel (4–128) multidetector-row CT (MDCT) scanners. The instrument used most frequently was a 128-detector-row MDCT scanner (Definition AS+, Siemens Medical Solutions, Forchheim, Germany), which was used in six patients. These CT examinations were performed after injection of intravenous contrast medium (Iopromide, Ultravist 300; Bayer Healthcare, Berlin, Germany). The images were acquired during the portal venous phase (70-second delay after contrast injection), including the region from the dome of the diaphragm to the symphysis pubis. The CT parameters were as follows: 100 kVp, quality reference current, 220 mAs; detector configuration 0.6 × 32 mm; pitch, 1.25; rotation time 0.5 seconds; section thickness 4.0 mm; reconstruction interval 4 mm, and reconstruction kernel B30f. Tube current modulation with CAREDose4D (Siemens Medical Solutions) was applied. Routine transverse and coronal images were reconstructed on the scanner’s standard workstation (Syngo Multi-Modality Work Place, Siemens Medical Solutions).

The images were retrospectively reviewed by a consensus of three experienced abdominal radiologists. Studies were evaluated for the following:

- visualization and localization of Meckel’s diverticulum on the preoperative MDCT, which defined as blind-ending out-pouching sac like structure arising from distal ileum;
- complication type of Meckel’s diverticulum;
- location of SBO;
- grade of SBO, which categorized as high-grade obstruction was considered present if there was a 50% difference in caliber between the proximal dilated bowel and the distal collapsed bowel, or complete evacuation of the contents of the bowel segments distal to the obstruction point [6];
- identification of a normal appendix;
- other associated findings.

Radiology reports were reviewed, to determine the patient presenting complaint and the prospective preoperative diagnosis offered at the time of initial MDCT interpretation.

Results

Ten patients (9 males and one female) were enrolled in this study, and their detailed characteristics are summarized in Table 1. The average age was 21 years (range 2–44). All patients complained of abdominal pain. In addition, three patients had diarrhea, five had vomiting, and one had fever to 39.5°C. Review of radiology records showed that the prospective MDCT diagnosis raised the possibility of SBO caused by Meckel’s diverticulum in five of the ten patients. In five patients, the CT interpretation offered prospectively was SBO of uncertain cause. SBO was graded as high (n = 6) or low (n = 4).

Of the five diverticula visualized, the location was in the midline in two patients, slightly to the right of midline in one, and to the left of midline in one. The diverticulum was located in the right lower quadrant in one patient. All diverticula were located on the terminal branch of the superior mesenteric artery (Fig. 1). Diverticulitis was present in three patients, with evidence of inflammatory changes, such as mural thickening, mural enhancement, and soft tissue stranding with adjacent fluid collections. Of these, perforated diverticulitis was pathologically proven in two patients with extraluminal free air, and small bowel enterocolitis was present in one patient, but there was
Table 1  MDCT findings of SBO caused by Meckel’s diverticulum.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Gender&lt;sup&gt;a&lt;/sup&gt; / age</th>
<th>Visualized Meckel’s diverticulum</th>
<th>Connection with terminal branch of SMA</th>
<th>Previous surgical history</th>
<th>Visualized appendix</th>
<th>SBO grade</th>
<th>Other complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M/16</td>
<td>No</td>
<td>Yes</td>
<td>Yes&lt;sup&gt;b&lt;/sup&gt;</td>
<td>No</td>
<td>Low</td>
<td>Meckel’s diverticular perforation</td>
</tr>
<tr>
<td>2</td>
<td>M/12</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>High</td>
<td>Inflammatory change in the mesentery</td>
</tr>
<tr>
<td>3</td>
<td>F/4</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Low</td>
<td>Jejuno-jejunal intussusception</td>
</tr>
<tr>
<td>4</td>
<td>M/2</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>High</td>
<td>Fibrous band formation (mesodiverticular band)</td>
</tr>
<tr>
<td>5</td>
<td>M/12</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>High</td>
<td>Meckel’s diverticular perforation</td>
</tr>
<tr>
<td>6</td>
<td>M/35</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>High</td>
<td>Inverted Meckel’s diverticulum</td>
</tr>
<tr>
<td>7</td>
<td>M/34</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>High</td>
<td>Meckel’s diverticulum torsion and necrosis</td>
</tr>
<tr>
<td>8</td>
<td>M/21</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>High</td>
<td>Meckel’s diverticulitis</td>
</tr>
<tr>
<td>9</td>
<td>M/32</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Low</td>
<td>Meckel’s diverticular perforation</td>
</tr>
<tr>
<td>10</td>
<td>M/44</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Low</td>
<td></td>
</tr>
</tbody>
</table>

SBO: small bowel obstruction; MDCT: multidetector-row computed tomography; SMA: superior mesenteric artery.

<sup>a</sup> Gender: male (M) and female (F).

<sup>b</sup> Patient underwent appendectomy 10 years ago.

no extraluminal free air in the other patient. Diverticular torsion and necrosis were present in one patient, with a swirling, torsion knot-like structure attached to the adjacent ileum, and an approximately 11 × 5 cm pouch-like lesion with an air-fluid level located just inferior to the torsion knot. Inverted Meckel’s diverticulum was present in one patient with ileo-ileal intussusception containing an elongated mass of fat, with soft tissue attenuation and trapped peritoneal fluid. A normal appendix was visualized in all five patients, and none had previous surgery.

In the five patients in whom the diverticulum was not visualized on the preoperative MDCT, the distal ileum was the transition zone in four patients, and the distal jejunum in a single patient with jejuno-jejunal intussusception located in the left lower quadrant. Of the four patients in whom the distal ileum was identified as a transition zone, it was located at the midline in two, slightly to the right of midline in two. In two patients (40%), transition zone of the ileum was identified at the terminal branch of the superior mesenteric artery (Figs. 2 and 3). Additional findings in two patients were a converging beak-shaped ileum, which corresponded to adhesive band formation of the Meckel’s diverticulum and mesentery, and resultant ileal herniation through the band at pathology (Fig. 4).

Inflammatory changes were present in the adjacent mesentery in four patients, and mesenteric fluid was present in three patients. Extraluminal free air was present in one patient, who had a pathologically proven perforated Meckel’s diverticulum. A normal appendix was visualized in four patients, and one underwent appendectomy 10 years ago, thus excluding the diagnosis of acute appendicitis.

Discussion

The aim of the present study was to document the MDCT finding of SBO caused by Meckel’s diverticulum.

A Meckel’s diverticulum is true diverticulum containing all layers of the intestinal wall and arises from failure of obliteration of omphalomesenteric duct (vitellointestinal duct) which connects between midgut and yolk sac before seventh to eight weeks of embryogenesis. The diverticulum usually occurs within 100 cm of the ileocecal valve in the antimesenteric border of ileum. The diverticulum has various sizes up to 15 cm in length [7]. The arterial supply comes from the remnant of the omphalomesenteric (vitellointestinal) artery, which is a terminal ileal branch of the superior mesenteric artery.
Figure 1. A 35-year-old man with abdominal pain and diarrhea (patient 6). a: contrast-enhanced MDCT of the abdomen shows an enhancing walled, blind-ended, out-pouching structure (thick arrow) of the ileum; fat infiltration in the small bowel mesentery was identified; b, c: MDCT scan obtained slightly more superior to the level in (a), and the coronal reformatted image reveals a terminal branch of the superior mesenteric artery (thin arrow) supplying the Meckel’s diverticulum. Meckel’s diverticular perforation was surgically proven.

Figure 2. A 16-year-old boy with abdominal pain (patient 1). a: contrast-enhanced MDCT of the abdomen represents an enhancing walled, blind-ended, out-pouching structure (thick arrow) of the ileum identified at the terminal branch of the superior mesenteric artery (thin arrow); b: MDCT obtained slightly more superior to the level in (a) shows free air pockets in the interloopal space (thin arrow). At pathology, Meckel’s diverticular perforation was confirmed.

Figure 3. A 12-year-old boy with abdominal pain and vomiting (patient 2). a, b: contrast-enhanced MDCT of the abdomen displays an enhancing walled, blind-ended, out-pouching structure (thick arrow) of the ileum identified at the terminal branch of the superior mesenteric artery (thin arrow). At pathology, Meckel’s diverticulitis was confirmed.
The complication rate in total lifetime of a Meckel’s diverticulum is approximately 4% [8,9]. Complications include bleeding, obstruction, inflammation or perforation. Gastrointestinal bleeding occurs as a result of ulceration of the diverticulum by secretion of acid from ectopic gastric mucosa and may present in infants under the age of 2 years [7]. Small bowel obstruction is the main complication seen in adults, resulting from various mechanisms. Mechanisms include intussusception from diverticulum as a lead point, volvulus or internal herniation by a persistent fibrous band between the Meckel’s diverticulum and mesentery or luminal narrowing of ileum due to inflamed diverticulum [5,10–12]. In our series, the grade of the SBO complicated by Meckel’s diverticulum varied considerably. Six patients had high-grade small bowel obstruction, and four had low-grade obstruction.

Of the five diverticula identified on the preoperative MDCT, there was evidence of diverticulitis (n = 3), diverticular torsion and necrosis (n = 1), and inverted Meckel’s diverticulum (n = 1). All diverticula (100%) were located at the terminal branch of the superior mesenteric artery, which is thought to be the remnant of the omphalomesenteric (vitellointestinal) artery supplying Meckel’s diverticulum. In the five patients in whom the diverticulum was not visualized on the preoperative MDCT, transition zones were small bowel loops in the right lower quadrant (suspected ileal loops) (n = 4), and in the left paramedian abdomen (n = 1). Converging, beak-shaped ileum (n = 2), inflammatory change in the adjacent mesentery (n = 4), and mesenteric fluid (n = 3) were also seen. In this setting, the CT features are similar to those of small intestinal obstruction secondary to postoperative adhesions. However, in two patients (20%), transition zone of the ileum was identified retrospectively at the terminal branch of the superior mesenteric artery. Therefore, we suspected that obstruction was due to Meckel’s diverticulum.

The majority of Meckel’s diverticula visualized on preoperative MDCT in our study were located at or near midline. In the five patients in whom the diverticulum was not visualized on preoperative CT, transition zones were located at or near the midline (80%). Also, the arterial supply comes from the vitelline artery, which is a branch of the superior mesenteric artery, suggesting midline of the midgut during the early embryological stage. Our study reveals that meticulous trace of the distal ileal branch of the superior mesenteric artery helps to diagnose SBO related to complicated Meckel’s diverticulum.

The patient’s age of the non-visualized group was less than 20 years old. On the other hand, that of visualized group was over 20 years old. Therefore, it might explain

Figure 4. A 2-year-old boy with abdominal pain and vomiting (patient 4). a, b: contrast-enhanced MDCT of the abdomen shows converging beak-shaped distal ileal loops (arrows) and dilated proximal small bowel loops. Note that transition zone is located slightly to the right of the midline; c: during the operation, the congenital fibrous band of Meckel’s diverticulum and the mesentery and resultant ileal hernia through the band were confirmed.
that Meckel’s diverticulum was not seen in MDCT of pediatric group because the Meckel’s diverticulum and ileum are not fully grown as other organs of body. Incidentally, two patients (40%) of pediatric group were SBO due to congenital fibrotic band between the Meckel’s diverticulum and mesentery. But in adult, no adhesive band formation was seen and there are diverticulitis ($n = 3$), diverticular torsion and necrosis ($n = 1$), and an inverted Meckel’s diverticulum ($n = 1$). In our study group, majority (90%) of patients were male patients except one female patient, however, the male-to-female ratio is usually reported to be 2:1 to 4:1 [9,11,13]. Thus, the male preponderance in our sample may be related to the small sample size.

This study has several limitations. First, it was performed retrospectively, and the sample was small. Second, we defined SBO based on CT findings. In addition, our ability to rate the degree of obstruction was limited because SBO can change depending on cause and time.

In conclusion, the diagnosis can be made with certainty when the diverticulum is visualized at the site of obstruction. However, the preoperative diagnosis is difficult if the Meckel’s diverticulum is not noted on the MDCT. In this setting, the MDCT features are similar to those of SBO secondary to adhesive ileus. However, we suggest that the diagnosis of SBO caused by Meckel’s diverticulum should be kept in mind when the patient was male, age <40, no prior abdominal surgery, fluid-and-air-filled blind-ending pouch arising from the distal ileum, lower abdomen and midline location, at the terminal branch of the SMA.

**Disclosure of interest**

The authors declare that they have no competing interest.

**References**