Original Article

Bowel dilatation on computed tomography: diagnosis of lower gastrointestinal tract perforations

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Abstract: Objective: To evaluate bowel dilation as an indirect finding predictive of lower gastrointestinal tract (GI) perforation using multidetector computed tomography (MDCT). Methods: This study retrospectively enrolled 93 consecutive patients presenting with extraluminal air (EA) on MDCT. Two reviewers independently evaluated bowel dilation of each segment and the dilation region in each patient. Results: The incidence of obstructive bowel dilation was 0% in upper GI tract perforation cases and 82.61% in lower GI tract perforation cases, respectively. Significant differences (P<0.05) were observed in the dilation degree between the lower and upper GI tract perforations. The sensitivity of bowel dilation for the detection of lower GI tract perforations was 82.61%, higher than that of the upper GI tract perforation (0%). Significant difference in sensitivity (P<.001) was observed. And multiple causes lead to intestinal perforation accompanied by obstructive bowel dilation. Conclusions: Obstructive bowel dilation could be an indirect CT finding to identify the upper and lower GI tract perforations with high sensitivity.

Keywords: Dilation degree, MDCT, perforation site, gastrointestinal tract, bowel

Introduction

Lower gastrointestinal tract perforation is a life-threatening emergency condition [1]. Early diagnosis and prompt surgical treatment are critical in most cases due to serious complications and high morbidity and mortality [2-7]. MDCT has played an important role in the diagnosis of gastrointestinal (GI) perforations because of rapid technological advances, such as fast volume scan, thin-slice reformation and multiplanar reformation [8-10]. A radiologist can identify a perforation and predict the perforation site based on direct and indirect CT findings. A direct sign is a ruptured gastrointestinal wall [11]. Indirect signs mainly include free air location, segmental bowel wall thickening, mottled extraluminal air bubbles, perienteric fatstranding, and localized fluid collection [12]. The diagnostic accuracy of relies on CT imaging findings, as mentioned previously [8-11]. Compared to upper GI tract perforations, it is a challenge for radiologists to predict a perforation site in the lower GI tract with high sensitivity and specificity [10-12]. Some trials have distinguished upper and lower GI tract perforations based on some CT findings, such as free air signs and attenuation values of ascites, both of which influence the differential diagnosis [13, 14].

A variety of causes combined with intestine movement make the accurate identification of the perforation site difficult, particularly when direct CT findings are subtle in the long tracts of the small and large bowels [15-20]. Common pathologies of bowel perforations include ischemic and infective causes, Crohn’s disease, abdominal trauma, tumors, diverticulitis, hernia and foreign body ingestion. The majority of the pathogeneses noted above influence intestinal motility, resulting in bowel dilatation, pneumatosis, and even acute intestine obstruction [16-18]. To the best of our knowledge, few articles have described bowel dilation in perforations based on CT findings [16, 19]. In this study, we examined bowel dilation in gastrointestinal perforations and analyzed the differences in dilation between upper and lower GI tract perforations based on CT images. We also evaluated the sensitivity for the dilation sign for diagnosis of lower GI tract perforation based on the operation results.
Bowel dilatation on CT

Materials and diagnosis

Patient selection

The protocol for the entire retrospective study was approved by the hospital ethics committee, and the requirement for informed consent was waived. We reviewed patients with surgically confirmed GI tract perforations with exhibiting extraluminal air on MDCT, excluding penetrating abdominal trauma, treated between March 2009 and March 2015 in our hospital. A total of 93 consecutive patients (52 males and 41 females; mean age 62.8 years; range 24-96 years) were enrolled in this study, and no patient had a history of abdominal surgery, acute pancreatitis or hypokalemia. Patients were divided into two groups as follows. The upper GI tract perforation group (n = 47, M:F = 28:19, age range: 24-96 years, mean: 60.8 years) included patients with gastroduodenal perforations, and the lower GI tract perforation group (n = 46, M:F = 24:22, age range: 26-90 years, mean: 65.1 years) included patients with gastroduodenal perforations, and the lower GI tract perforation group (n = 46, M:F = 24:22, age range: 26-90 years, mean: 65.1 years) included patients with small, appendix and large bowel perforations. There were no significant differences in age or gender between the two groups (P > 0.005, t test).

According to the available medical records, all patients visited the emergency room and underwent CT scans within 2 hours after seeing a doctor. All the patients had the surgery within 10 hours after the CT scan. A laparotomy was performed in all 93 cases. The causes and the perforation sites based on the surgical records and pathological results are shown in Table 1.

CT protocol

All CT examinations were performed using a 128-detector row CT scanner (Definition AS; Siemens Medical Solutions, Forchheim, Germany). Abdominal CT scanning was performed with a collimation of 128 × 0.6 mm. The effective current was set at 200 mA, and tube voltage was set at 120 kVp. Unenhanced and enhanced CT scans from the diaphragmatic dome to the symphysis pubis were performed. Neither oral nor rectal contrast material was used. Contrast-enhanced CT

Table 1. Perforation site and causes in 93 patients

<table>
<thead>
<tr>
<th>Causes</th>
<th>Upper GI tract perforation (n = 47)</th>
<th>Lower GI tract perforation (n = 46)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>D</td>
</tr>
<tr>
<td>Ulcer</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>Tumor</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Blunt trauma</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>NSIF</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Diverticulum</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Foreign body</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Hernia</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Fecal obstruction</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Dilation range in the patients with upper and lower GI tract perforation

<table>
<thead>
<tr>
<th>Dilation range</th>
<th>Upper GI tract perforation (n = 47)</th>
<th>Lower GI tract perforation (n = 46)</th>
<th>Small bowel perforation (n = 15)</th>
<th>Large bowel perforation (n = 31)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>47 (100.00%)</td>
<td>8 (17.39%)</td>
<td>3 (20.00%)</td>
<td>5 (16.13%)</td>
</tr>
<tr>
<td>Positive +</td>
<td>0 (0.00%)</td>
<td>38 (82.61%)</td>
<td>12 (80.00%)</td>
<td>26 (83.87%)</td>
</tr>
<tr>
<td>P = 0.001</td>
<td>P = 0.745</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N = the number of patients. Data in parentheses are the percentages. Statistically significant (P < 0.05).

Figure 1. A 67-year-old woman suffering from an ascending colon carcinoma and perforation of the cancer (A) accompanied by significant dilation of the proximal colon and cecum (B), as shown in axial enhanced CT images.
**Bowel dilatation on CT**

**Figure 2.** A 66-year-old woman suffering from sigmoid-rectum carcinoma and perforation of the cancer accompanied by proximal colon and small intestine dilation, as shown in coronal enhanced (A, C), axial enhanced (B) and sagittal enhanced (D) CT images.

**Figure 3.** A 48-year-old man suffering from a fracture of the rectum and sigmoid colon accompanied by proximal small intestine dilation, as shown in coronal enhanced (A) and axial enhanced (B) CT images.
Bowel dilatation on CT

Figure 4. A 75-year-old man suffering from sigmoid colon perforation (A) due to non-specific inflammation accompanied by distal rectum dilation (B) as shown in the axial-enhanced CT images above.

Figure 5. A 80-year-old woman suffering from small intestine perforation due to the ingestion of a date pit (A) accompanied by proximal mild intestine dilation (B), as shown in the axial plain scan CT images above.

was performed after intravenous injection of 100-130 ml of iodinated contrast medium (iopromide, Ultravist 300; Bayer Schering Pharma, Berlin, Germany) at a rate of 3 ml/s through an antecubital vein. Scanning was performed 100 s after the initiation of the contrast medium injection. Axial CT images were obtained with 0.6 mm thickness at 0.6 mm intervals. The enhanced raw data were reformatted in the coronal and sagittal planes.

Image evaluation

All obtained images were loaded onto a PACS workstation (SyngoTM, Siemens Medical Solutions). The bowel dilation criteria was designed subjectively and the intestine was subjectively divided into thirteen segments, as shown in Table 2 and Figures 1-5. Two skilled radiologists (Reader 1 and Reader 2, with 20 and 15 years’ experience in abdominal imaging, respectively) independently judge each segment dilation according to the criteria above. The scores of each segment from the two viewers were compared. Disagreements in scoring were resolved by discussion. The readers were blinded to the surgical results, and they did not know the design or purpose of the study.

Statistical analysis

The small and large bowel dilations in 93 cases were evaluated. The sensitivity for the dilation sign for the diagnosis of lower GI tract perforation were analyzed also based on the operation results. Statistical significance was considered for p values <0.05. Using the surgical records and pathological results, the etiology of the lower GI tract perforations was classified into 5 groups: neoplasms, blunt abdominal trauma, non-adhesive inflammation, adhesive or strangulated inflammation, and foreign body ingestion. The dilation degree of each group was analyzed. The statistical analysis was performed using SPSS 17.0 (SPSS Inc., Chicago, USA).

Results

The differences in the degree of dilation between the lower and upper GI tracts

The severity of dilated degree in the upper and lower GI tract perforations are listed in Table 2. Obstructive bowel dilation was not found in 47 cases of upper GI tract perforations. In 46 cases of lower GI tract perforation, dilation was identified in 38 patients (82.61%). Significant differences in the degree of dilation between upper and lower GI tract perforations were observed (P<.0001, rank sum test). In 15 cases with small bowel perforations, 12 were accompanied by bowel dilation (80%). And 95.45% of dilated segments were located in the small intestine. Of the 31 patients with large bowel perforations, 26 had bowel dilation (83.87%). The percentages of dilated segments located in the small and large bowels were 55.56% and 44.44%, respectively. Significant differences in the distribution of the dilated bowels between the small and large bowel perforations was found (P<.0001, chi-square test).
Bowel dilatation on CT

Table 3. Dilation degree in the lower GI tract perforation group with different causes

<table>
<thead>
<tr>
<th>Tumor (n = 18)</th>
<th>Blunt abdominal Trauma (n = 9)</th>
<th>Adhesive or strangulated Inflammation (n = 7)</th>
<th>Non-adhesive Inflammation (n = 9)</th>
<th>Ingestion of a foreign body (n = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive (+)</td>
<td>1, 0.5</td>
<td>16 (88.89%)</td>
<td>7 (77.78%)</td>
<td>7 (77.78%)</td>
</tr>
<tr>
<td>Negative (-)</td>
<td>0</td>
<td>2 (11.11%)</td>
<td>2 (22.22%)</td>
<td>0 (0.00%)</td>
</tr>
</tbody>
</table>

N = the number of patients. Data in parentheses are the percentages.

Sensitivity of bowel dilation in upper and lower GI tract perforations

According to operation results, 38 cases were accompanied with bowel dilation in lower GI tract perforations, and 0 cases in upper GI tract perforations. The sensitivity for the detection of lower GI tract perforations was 82.61%, higher than that of the upper GI tract perforation. Significant difference in sensitivity ($P<.0001$) was observed.

Bowel dilation of lower GI tract perforations with different causes

Five causes of lower GI tract perforations were identified: neoplasms, blunt abdominal trauma, non-adhesive inflammation, adhesive or strangulated inflammation, and foreign body ingestion. Based on the degree of dilation, we classified 46 cases into negative (-) and positive (+) groups. The number of cases and the degree of dilation in each group are listed in Table 3.

In the 46 cases in the lower GI tract perforation group, neoplasms, blunt abdominal trauma, and foreign body ingestion were the main causes, from most to least. In 18 cases with tumors, 16 (88.89%) had dilation. Because of lumen stenosis and increased pressure, dilation often occurred in the proximal intestines. Cancers in the ascending colon could result in significant dilation of the cecum, as shown in Figure 1. Sigmoid and rectum carcinomas could lead to proximal colon and small intestine dilation, as shown in Figure 2. These findings were in accordance with previous studies [20]. Bowel obstructions due to the adhesive or strangulated inflammation [2] are a common cause of lower GI tract perforations. Dilation of multiple bowel loops is common in obstructions, and this could be found in each case of bowel perforation caused by bowel obstruction. This could explain why significant bowel dilation was found on the CT images in all 7 cases of adhesive or strangulated inflammation. Blunt abdominal trauma is another common cause of GI tract perforations. The 9 patients suffering from blunt trauma included 3 cases of small intestine perforation (33.33%) and 6 cases of sigmoid colon or rectum fracture (66.67%). Significant bowel dilation in the proximal bowel of the perforation site was found in 7 cases. Depending on the anatomy structure, the perforation site could be far away the dilated segments, as shown in Figure 3. In these cases, the perforation site was located at the junction of the sigmoid colon and rectum, resulting in significant dilation of the small intestine because of edema of the intestinal wall. Three patients had ingested foreign bodies (date pits). The perforation sites were in the small intestine, and mildly dilated intestines were found in one case, as shown in Figure 4. In this case, the local proximal bowel was mildly dilated. The reason for negative findings in two cases may have been that the patients saw a doctor immediately and edema of the intestinal wall did not result in lumen stenosis. In non-adhesive inflammation cases, the incidence of bowel dilation was lower than that in adhesive or strangulated inflammation cases in this study. In 9 cases with non-adhesive inflammation, dilation was found in 7 patients, as shown in Figure 5, who suffered from diverticulitis.

Discussion

Among all the 93 cases of this study, there were no significant differences in age or gender between the two groups. Although surgical treatment was performed without delay in each case, there were 3 cases of postoperative death due to the acute diffuse peritonitis and shock in the lower GI tract perforation group. This indicates that peritonitis and septic shock secondary to large bowel perforation remains a major clinical life-threatening condition associated with high morbidity and mortality [3].

In this study, there was a significant difference in the dilation severity between the upper and
Bowel dilatation on CT

lower groups. In the 36 positive cases of lower GI tract perforations, 38 (82.61%) had bowel dilation. By viewing the CT images, some indirect signs, such as segmental bowel wall thickening, mottled extraluminal air bubbles, perienteric fat stranding, and localized fluid collection around the mildly dilated bowel were found. In the upper GI tract group, there was no case with dilated bowels, only some bowels with pneumatosis. The pneumatosis segments were not close to the perforation sites, and the indirect CT signs noted above were not found around the bowel. This indicates that dilation of the bowel is a useful indirect sign for evaluating lower GI tract perforations. However, bowel with pneumatosis is not a reliable sign of upper or lower GI tract perforations. The direct sign of a ruptured gastrointestinal wall may not be significant in CT images when the bowsels are slightly dilated [8-10]. In this case, mildly bowel pneumatosis is not surrounded by the indirect findings mentioned above, so we could infer that the perforation site might be in the upper GI tract. On the other hand, if the dilated small or large bowel is surrounded by the indirect findings mentioned above, a lower GI tract perforation could be inferred, even though a ruptured intestinal wall might not be found.

In this study, the percentages of bowel dilation in the small and large bowels were 80% (12/18) and 83.87% (26/31), respectively. In the 12 cases of small intestine perforations, all dilated segments were distributed among the small bowel. In the 38 cases of large bowel perforations, 20 segments were located in the small bowel and combined with large bowel dilation, while 18 segments were located in the large bowel merely. No significant differences were found in degree between small intestine and large bowel perforations. However, there was significant difference in the distribution of dilated segments between the small and large bowel perforations. This indicates that dilation degree alone could not be used as indirect CT finding to identify the perforation site in the large and small bowel, regardless of the location of dilation.

In this study, the sensitivity of bowel dilation in lower GI tract perforation was 82.61%. The accuracy of CT for predicting the site of bowel perforation has been reported to range from 72% to 87% [11]. This indicates bowel dilation could be a useful CT finding to determine the perforation site, the same as other indirect CT findings. The perforation site is important information for surgeons and has important reference value for therapeutic strategies. If significant bowel dilation (a sign of the bowel obstruction) was found in CT images, radiologists should pay more attention to the lower GI tract depending on other CT findings. Local mild bowel pneumatosis surrounded by other indirect CT findings suggests a lower GI tract perforation. If only local mild bowel pneumatosis is found without indirect CT findings nearby, radiologists should observe the entire digestive tract to identify the perforation site.

The etiology may be one important factor responsible for the significant differences in dilation severity and location between small and large bowel perforations, as noted above. The lower digestive tract is so long that a perforation of any part of the bowel from any cause could affect intestinal motility. The causes of gastrointestinal perforations, such as tumors, adhesive inflammation, and hernia, may lead to lumen stenosis and secondary complete or partial intestinal obstruction. The part of the tract proximal to the site of the obstruction dilates and fills with secretions and air [21]. The lower the perforation site, the broader the dilated bowel will be. The dilation range shown in this study also indicates that upper GI tract lesions may have less influence on small and large bowel movements and little chance of causing a lower GI obstruction.

Some limitations of our study protocol required to be considered. First, the number of patients suffering from lower GI tract perforations was relatively small, which might have influenced the assessment of the percentage of bowel dilation according to the each GI tract site with different causes. However, the concrete data were not introduced in previous studies [9-11]. In our future study, the degree of bowel dilation need be analyzed in more perforation cases with different causes. Second, small amounts of gas were found under normal conditions in some cases, which may increase the positive incidence of mildly dilated bowels in both upper and lower GI tract perforations [21]. Therefore, prospective studies are needed to determine whether mild bowel dilation is useful in identifying the perforation site. Third, one of the inclusion criteria used in this study was that the patient had to exhibit extraluminal air on a CT
Bowel dilatation on CT

examination. Therefore, the application of the degree of dilation to diagnose the perforation sites would be limited if extraluminal air was not shown.

In summary, the degree of bowel dilation could be used as an indirect CT finding to identify upper and lower GI tract perforations. For cases with bowel dilation, the dilation location and severity may provide useful information to predict the perforation site.

Disclosure of conflict of interest

None.

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References


Bowel dilatation on CT


