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Unenhanced Computed Tomography to Visualize Hollow Viscera and/or Mesenteric Injury After Blunt Abdominal Trauma

A Single-Institution Experience

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Abstract: To identify and describe the major features of unenhanced computed tomography (CT) images of blunt hollow viscera and/or mesenteric injury (BHVI/MI) and to determine the value of unenhanced CT in the diagnosis of BHVI/MI.

This retrospective study included 151 patients who underwent unenhanced CT before laparotomy for blunt abdominal trauma between January 2011 and December 2013. According to surgical observations, patients were classified as having BHVI/MI (n = 73) or not (n = 78). Sensitivity, specificity, *P* values, and likelihood ratios were calculated by comparing CT findings between the 2 groups.

Six significant CT findings ($P < 0.05$) for BHVI/MI were identified and their sensitivity and specificity values determined, as follows: bowel wall thickening (39.7%, 96.2%), mesentery thickening (46.6%, 88.5%), mesenteric fat infiltration (12.3%, 98.7%), peritoneal fat infiltration (31.5%, 87.1%), parietal peritoneum thickening (30.1%, 85.9%), and intra- or retro-peritoneal air (34.2%, 96.2%).

Unenhanced CT scan was useful as an initial assessment tool for BHVI/MI after blunt abdominal trauma. Six key features on CT were correlated with BHVI/MI.

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Abbreviations: BHVI/MI = blunt hollow viscera and/or mesenteric injury, CT = computed tomography.

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INTRODUCTION

The incidence of blunt hollow viscera and/or mesenteric injury (BHVI/MI) following blunt abdominal trauma ranges from approximately 1% to 5%.[1] Although relatively uncommon, BHVI/MI is strongly associated with morbidity and mortality. Identifying BHVI/MI can be challenging, especially in the first few hours after injury. Clinical examinations often yield no reliable indications during the initial assessment period.[2,3] Patients with multiple extra-abdominal injuries might divert a surgeon's time and attention away from other potentially life-threatening intra-abdominal pathologies. Consequently, a diagnosis could potentially be delayed until fatal peritonitis or life-threatening hemorrhage has become well-established. Some authors have suggested that delays of 8 to 12 h in diagnosing BHVI/MI could increase the morbidity and mortality from severe complications like peritonitis and sepsis.[4–6] With advances in the speed and accuracy of imaging, computed tomography (CT) has become a mainstay diagnostic modality for the early evaluation of blunt abdominal trauma. The use of CT has increased the number of patients with blunt abdominal injury who are subsequently treated conservatively with regard to surgery. However, the efficacy of CT is controversial in the diagnosis of BHVI/MI because delayed diagnosis increases mortality and morbidity for these patients, especially in the absence of solid organ injury.[7,8]

BHVI/MI is typically diagnosed with the aid of contrast-enhanced CT. However, the use of oral and intravenous contrast agents in trauma patients is a controversial issue.[9,10] As is the case for several institutions in China, our emergency department does not routinely administer CT contrast agents after blunt abdominal trauma. Therefore, the purpose of this study was to explore the value of unenhanced CT in diagnosing BHVI/MI.

METHODS

This retrospective study was approved by the institutional review board at our institution, and the need to obtain informed consent was waived. All patients admitted to West China Hospital (a Chinese Level I trauma center) between January 2011 and December 2013 who had sustained blunt abdominal trauma and underwent an unenhanced CT scan before laparotomy were identified from the trauma database. The need for a laparotomy was usually determined on the basis of clinical findings (pain, tenderness, distension, hypotension, tachycardia, etc.), blood tests, and imaging examinations (especially CT) together. Patients were excluded from the study if they had suffered penetrating abdominal trauma or iatrogenic injury, underwent laparotomy before arriving at our hospital,

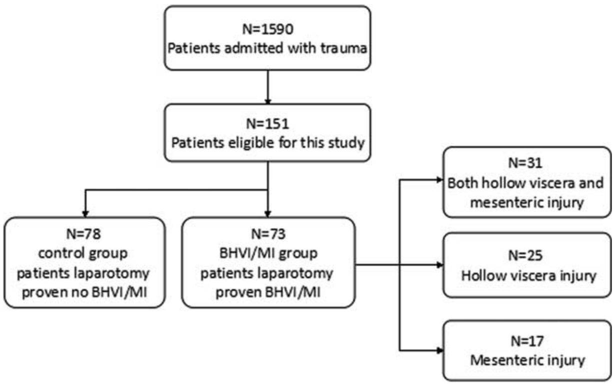

FIGURE 1. Study flowchart.

had CT performed only after the laparotomy, had an initial CT scan performed but were managed conservatively, or had no preoperative CT scan even though they underwent a laparotomy.

Age, sex, mechanism of injury, location and type of BHVI/MI, solid organ injury, and CT images were collected from the database. On the basis of the laparotomy findings, patients were divided into 2 groups (Figure 1): patients with identifiable BHVI/MI, with or without solid organ injury on laparotomy (BHVI/MI group), and patients who sustained only solid organ injury without BHVI/MI (control group). To compare the CT findings between these groups, the sensitivity, specificity, *P* value, and likelihood ratios were calculated for each imaging feature.

CT Scanning

Any patient who was hemodynamically unstable, had signs of an acute abdomen, incurred penetrating abdominal trauma, or had positive peritoneal lavage was not suitable for CT scan. Indications for CT examination included: high clinical suspicion of abdominal trauma (abdominal tenderness, seat belt sign, distention, mechanism of injury, etc.), gross hematuria, rectal bleeding, dropping or low hematocrit, and neurologic obtundation. CT scans were conducted in the emergency department on a 64-detector helical CT scanner (Siemens, Forchheim, Germany). For trauma patients in emergency settings, CT scans are routinely performed at our hospital without the administration of intravenous or oral contrast agents. Images were acquired at 1-mm intervals at a pitch of 1:1 from the diaphragm to the symphysis pubis.

CT Image Evaluation

A staff radiologist who was blinded to the findings from laparotomies reviewed the CT images. Previous studies have evaluated numerous CT features indicating BHVI/MI secondary to blunt abdominal trauma. Some frequently described features include intra- or retro-peritoneal air or fluid, bowel wall or mesentery thickening, bowel wall discontinuity, and mesenteric fat infiltration. Less frequently noted features include increased bowel wall density, mesenteric air or fluid, mesenteric vessel abnormalities, interloop fluid, peritoneal fat infiltration, bowel dilatation, and parietal peritoneum thickening.

In this study, the density of the bowel wall was considered abnormal if it was greater than the density of the adjacent bowel segment. Similarly, the parietal peritoneum thickness was considered abnormal if it was thicker than the adjacent peritoneum. Mesenteric vessel abnormalities included vascular beading and abrupt termination of the mesenteric vessels. Interloop fluid was defined as free fluid between bowel loops. Peritoneal fat infiltration was regarded as nonmesenteric intra-abdominal fat. Bowel dilatation was defined as a colon diameter >8 cm or small bowel diameter >2.5 cm.[11]

Surgical Observations

During surgery, the following features were ascertained: injury location and presence of perforation of the hollow viscus, gangrenous or ischemic bowel tissue, partial thickness tearing of the bowel, bowel edema, bowel wall hematoma, mesenteric tearing, mesenteric hematoma, active mesenteric hemorrhage, and associated solid organ injury.

Statistical Analyses

Statistical tests were performed in the SPSS software program (version 13.0, SPSS, Chicago, IL). The Chi-squared test was used to compare categorical variables. P values <0.05 were considered statistically significant.

RESULTS

Study Population

Between January 2011 and December 2013, 1590 patients were admitted to our hospital for trauma. Ultimately, 151 patients were eligible for this retrospective case–control study (Figure 1). The BHVI/MI group included 73 consecutive patients with laparotomy-confirmed BHVI/MI who did or did not sustain solid organ injury during the same time period. The control group included 78 patients who underwent laparotomy to repair solid organ injuries and were confirmed not to have BHVI/MI. Demographic and injury data for the 2 groups are summarized in Table 1. With regard to the mode of injury in the BHVI/MI and control groups, motor vehicle collisions accounted for 52.1% versus 48.7% of cases. We were unable to obtain information from the medical records about the cause of injury for 1 patient in the control group.

TABLE 1. Patient Characteristics and Mechanism of Injury in the BHVI/MI and Control Groups

Characteristics	BHVI/MI Group	Control Group
Median age, y	41.4	35.1
Gender		
Male	61 (83.6)	57 (73.1)
Female	12 (16.4)	21 (26.9)
Mode of injury		
Motor vehicle collisions	38 (52.1)	38 (48.7)
Fall form heights	11 (15.1)	16 (20.5)
Fall	8 (11)	6 (7.7)
Assault	7 (9.6)	13 (16.7)
Falling object	7 (9.6)	4 (5.1)
Crush injury	1 (1.4)	0 (0)
Blast injury	1 (1.4)	0 (0)
Unknown	0 (0)	1 (1.4)

Data are reported as n (%).
BHVI/MI = hollow viscera and/or mesenteric injury.

TABLE 2. Location and Type of BHVI/MI

Location/Type	No. of Cases	Percentage*
Injury location		
Stomach	4	5.5
Small intestine	39	53.4
Colon	25	34.2
Mesentery	47	64.4
Total	115	
Injury type		
Perforation of hollow viscera	35	47.9
Gangrenous or ischemic bowel	7	9.6
Partial thickness tear of bowel	12	16.4
Bowel edema	16	21.9
Bowel wall hematoma	8	11.0
Mesenteric tear	21	28.8
Mesenteric hematoma	17	23.3
Active mesenteric hemorrhage	12	16.4
Total	128	

* Proportion of patients with BHVI/MI.
BHVI/MI = hollow viscera and/or mesenteric injury.

Surgical Observations and Management

In the BHVI/MI group, 17 patients sustained only mesenteric injuries and 25 patients had only hollow visceral injuries. The remainder (31 patients) suffered injuries to both the mesentery and hollow viscera. Locations and types of injuries to the hollow viscera and mesentery are described in Table 2. All intra- or retro-peritoneal fluid findings by CT were confirmed during laparotomy. Resections of ruptured or ischemic bowels were performed with 1-stage anastomosis or fistulization. Suture repairs were performed for partial thickness tears of bowels, mesenteric tears, and active mesenteric hemorrhages.

As shown in Table 3, coexisting solid organ injury requiring surgical treatment was observed in 32 (43.8%) patients in the BHVI/MI group. All patients in the control group sustained solid organ injuries but did not show evidence of BHVI/MI on laparotomy. Additionally, in the control group, laparotomies were nontherapeutic in 2 patients (2.6%) who did not require any visceral repair.

CT Scan Signs

All patients in the BHVI/MI group had abnormal CT findings (Table 4). The most common feature was intra- or retro-peritoneal fluid (Figure 2), found in 67 patients. Interloop fluid was present in 4 patients. Among patients who had hollow visceral perforations confirmed at laparotomy (n = 35), 25 patients (71.4%) had detectable intra- or retro-peritoneal air upon CT (Figure 2). The CT scans revealed mesenteric fat infiltration in 9 patients (Figure 3), whereas peritoneal fat infiltration was observed in 23 patients (Figure 4). Other findings observed on CT scans from patients in the BHVI/MI group included bowel wall thickening (n = 29; Figure 3), mesentery thickening (n = 34; Figure 3), bowel dilatation (n = 10; Figure 4), and parietal peritoneum thickening (n = 22; Figure 5). Additional features that were not obvious on CT scan included increased bowel wall density (n = 2), bowel wall discontinuity (n = 3), mesenteric air (n = 1), mesenteric fluid (n = 1), and mesenteric vessel abnormalities (n = 2; Figure 6).

Similar to the BHVI/MI group, the most common CT finding in the control group was intra- or retro-peritoneal fluid, which was seen in 68 patients. Other CT features that indicted BHVI/MI, but were false positives based on laparotomy findings, included intra- or retro-peritoneal air (n = 3), bowel wall thickening (n = 3), mesentery thickening (n = 9), mesenteric fat infiltration (n = 1), peritoneal fat infiltration (n = 10), bowel dilatation (n = 5), and parietal peritoneum thickening (n = 11; Table 4). CT features that indicated solid organ injury are not reported in this study.

TABLE 3. Solid Organ Injury Types in the BHVI/MI and Control Groups

Injury Type	Liver	Spleen	Kidney	Pancreas	Adrenal Gland
Rupture	10 (19)	16 (50)	1 (7)	4 (2)	0 (0)
Laceration	4 (2)	2 (1)	6 (4)	3 (1)	2 (5)
Total	14 (21)	18 (51)	7 (11)	7 (3)	2 (5)

Data are reported as n for BHVI/MI group (n for control group). In the BHVI/MI group, 32 patients had an associated solid organ injury.
BHVI/MI = hollow viscera and/or mesenteric injury.

Calculated Results

The sensitivity, specificity, and positive/negative likelihood ratios of CT features were calculated (Table 4). Six significant signs ($P < 0.05$), with their sensitivity and specificity values provided in parentheses, were as follows: bowel wall thickening (39.7%, 96.2%), mesentery thickening (46.6%, 88.5%), mesenteric fat infiltration (12.3%, 98.7%), peritoneal fat infiltration (31.5%, 87.1%), parietal peritoneum thickening (30.1%, 85.9%), and intra- or retro-peritoneal air (34.2%, 96.2%). These significant features also had high sensitivity and specificity to diagnose BHVI/MI. Features that showed 100% specificity but were associated with low sensitivities (1.4–5.5%) included increased bowel wall density, bowel wall discontinuity, mesenteric air, mesenteric fluid, mesenteric vessel abnormalities, and interloop fluid. These signs also had the highest positive likelihood ratios, which approached infinity.

DISCUSSION

We evaluated a series of unenhanced CT signs associated with BHVI/MI secondary to blunt abdominal trauma, and identified 6 significant CT findings ($P < 0.05$) for BHVI/MI and their corresponding sensitivity and specificity values for diagnosis. However, similar to previous reports, we were unable to identify many CT features that were both highly sensitive and specific for a diagnosis of BHVI/MI.

Motor vehicle collisions, which can generate multiple types of trauma (e.g., crush injury, shearing forces, burst injury),[12,13] were the most common cause of BHVI/MI. Small bowel and mesenteric injuries were the most common bowel injuries (39 and 47 injuries, respectively, in the BHVI/MI group), with a combined incidence of nearly 50%.[14] Other segments, such as the stomach and colon, were also involved.

The presence of intra- or retro-peritoneal air ($P < 0.01$) was a highly specific but insensitive feature for indicating gastrointestinal tract perforation, with a high positive likelihood ratio of 10.45, consistent with previous reports.[15,16] This sign

TABLE 4. Sensitivity, Specificity, *P* Values, and Likelihood Ratios of CT Features in the BHVI/MI and Control Groups

			Likelihood Ratio		
CT Feature	**Sensitivity, %**	**Specificity, %**	**Positive**	**Negative**	***P* Value**
Bowel wall thickening	39.7 (29/73)	96.2 (75/78)	10.44*	0.63	<0.01
Increased bowel wall density	2.7 (2/73)	100 (78/78)	Infinity*	0.97	0.232
Bowel wall discontinuity	4.1 (3/73)	100 (78/78)	Infinity*	0.96	0.111
Mesenteric thickening	46.6 (34/73)	88.5 (69/78)	4.05	0.60	<0.01
Mesenteric fat infiltration	12.3 (9/73)	98.7 (77/78)	9.46*	0.89	<0.05
Mesenteric air	1.4 (1/73)	100 (78/78)	Infinity*	0.99	0.483
Mesenteric fluid	1.4 (1/73)	100 (78/78)	Infinity*	0.99	0.483
Mesenteric vessel abnormality	2.7 (2/73)	100 (78/78)	Infinity*	0.97	0.232
Interloop fluid	5.5 (4/73)	100 (78/78)	Infinity*	0.95	0.112
Peritoneal fat infiltration	31.5 (23/73)	87.1 (68/78)	2.44	0.79	<0.01
Bowel dilatation	13.7 (10/73)	93.6 (73/78)	2.14	0.92	0.135
Parietal peritoneal thickening	30.1 (22/73)	85.9 (67/78)	7.34	0.81	<0.05
Intra- or retro-peritoneal air	34.2 (25/73)	96.2 (75/78)	10.45*	0.63	<0.01
Intra- or retro-peritoneal fluid	91.8 (67/73)	12.8 (10/78)	1.05	0.64	0.359

* Likelihood ratio is clinically significant.
CT = computed tomography, BHVI/MI = hollow viscera and/or mesenteric injury.

was previously shown to increase the probability of BHVI/MI with a positive likelihood ratio of >5.0.[17] Appearance of pneumoperitoneum on CT was determined by the amount of gas in the abdominal cavity, which can be restricted by small perforations, mucosal swelling, spontaneous perforation sealing by the bowel contents, or a developing ileus.[13] Small gas collections were not found frequently and were visualized as foci or bubbles outlining the anterior peritoneal surface in the perihepatic or perisplenic regions, mesentery, adhesions, or ligaments.[18] Under these conditions, setting the window width and window level could assist in the detection of small gas deposits.

Air was not identified in 10 patients with demonstrated bowel perforations during surgery. These false-negative results were due to perforations of the small intestine where gas does not routinely accumulate, rapid absorption of small amounts of gas by the peritoneum, or misinterpretation of CT results. Three false-positive cases were identified in the control group, which could be due to volume effects or intramural air. Although it was occasionally difficult to distinguish extraluminal from intramural air, the presence of both was more likely to suggest a full-thickness bowel injury.[19] In this study, 2 and 5 excluded patients presented with air due to the removal of a contraceptive device or the rupture of intraperitoneal bladders, respectively. Other causes of this finding that were not related to perforated bowels included peritoneal lavage, barotrauma and mechanical ventilation, and pneumothorax.[1,13] Therefore, whenever intra- or retro-peritoneal air is observed, other findings indicating bowel injury should be assessed.

Similar to previous studies, the most common CT finding in our study was retro- or intra-peritoneal fluid. Fluid may arise from hollow viscera or solid organ hemorrhage or leakage of

FIGURE 2. Traumatic perforation of the jejunum. Unenhanced CT scan shows air in subdiaphragmatic spaces (arrows) and fluid accumulation within the perihepatic and perisplenic regions (triangle). CT = computed tomography.

FIGURE 3. Traumatic laceration of the jejunum and mesentery. Unenhanced CT scan shows thickening in the wall of the jejunum (stars), mesenteric fat infiltration (triangle), and mesentery thickening (arrows). CT = computed tomography.

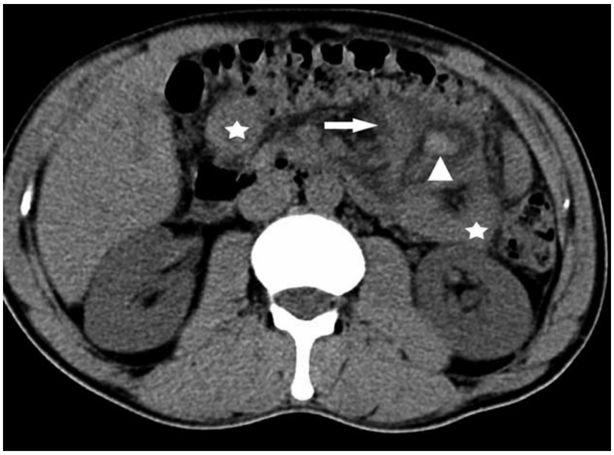

FIGURE 4. Traumatic perforation of the jejunum and renal laceration. Unenhanced CT scan shows bowel dilatation (arrows) and peritoneal fat infiltration (stars). CT = computed tomography.

FIGURE 6. Traumatic abrupt termination of the mesenteric vessels. Unenhanced CT scan shows a mesenteric vessel abnormality (arrows). CT = computed tomography.

bowel contents due to perforation of the hollow viscera. The similar occurrence rates of this finding in both groups may be explained by the high incidence of BHVI/MI associated with solid organ injury (32 patients, 43.8%). The presence of free fluid had a sensitivity of 91.8%, which remained high when both patient groups were analyzed together (89.4%). However, the specificity of fluid accumulation for diagnosing BHVI/MI was very low (12.8%), indicating that free peritoneal fluid is a sensitive but nonspecific finding for bowel or mesenteric injury.[20] Other authors have suggested that isolated free fluid in the absence of solid organ injury indicates the presence of an important bowel or mesenteric injury.[21,22] In this setting, exploratory laparotomy has been recommended to rule-out the possibility of hollow visceral injury.[23] Interloop fluid was identified in 4 patients in the BHVI/MI group. Because hemoperitoneum stemming from solid organ lacerations is rarely seen between the folds of the mesentery and bowel, interloop fluid was regarded as a key finding to suggest BHVI/MI,[18,19] even though there was no statistically significant difference between the 2 groups ($P = 0.112$).

FIGURE 5. Traumatic laceration of mesentery. Unenhanced CT scan shows intramural air (arrows) and thickening of the parietal peritoneum (triangle). CT = computed tomography.

Circumferential or localized thickening of the bowel loops or segments on CT might result from intramural hematoma after bowel wall contusion, ischemia secondary to mesenteric vascular injury, or congestion and edema in the bowel walls due to inflammation associated with intra-abdominal infection after blunt trauma. In our study, many more patients in the BHVI/MI group presented with bowel wall thickening compared to the control group ($P < 0.01$), with relatively high associated values of specificity (96.2%) and sensitivity (39.7%). These results suggest that bowel wall thickening is a good indicator of bowel injury, and that clinical follow-ups should be considered in patients with this finding. Bowel wall thickening could occur after hypoperfusion associated with bowel shock and other atraumatic diseases, such as intestinal tumor, hypoproteinemia, cirrhosis, or heart failure.[18,20,24]

Similarly, mesenteric and parietal peritoneum thickening were significant indicators with reasonable values of sensitivity and specificity. To the best of our knowledge, parietal peritoneum thickening has not been evaluated in previous studies. Peritonitis caused by the perforation of hollow viscera could lead to thickening of the adjacent parietal peritoneum. However, the parietal peritoneum adjacent to solid organs usually appeared aggravated in the presence of solid organ injury. Therefore, solid organ injuries should first be excluded before diagnosing injuries to the hollow viscera on the basis of this finding.

Mesenteric fat infiltration was a significant but less common feature, associated with a very high specificity but low sensitivity. Appearance of this finding on CT scans indicates inflammation caused by mesenteric injury.[25] Brody et al[19] suggested that this feature is related to hemorrhage and cell infiltration caused by damage or chemical stimulation, and is an early indication of mesenteric injury. By contrast, peritoneal fat infiltration was a relatively common finding, with relatively high values of sensitivity and specificity. We believe that the same causes of solid organ injury resulted in the stranding of the peritoneal fat. Thus, this feature had less significance to diagnose BHVI/MI than mesenteric fat infiltration, although it was significantly different between the groups in our study.

Despite being the primary feature of bowel injury,[19] bowel wall discontinuity was not a common feature in this study ($P = 0.111$). Similarly, although mesenteric vessel abnormalities were reported to indicate mesenteric injury with high sensitivity and specificity,[1,26] we found only 2 instances of this sign in our study ($P = 0.232$), both of which were identified during surgery. Bowel dilatation was detected in 13.7% of patients in the BHVI/MI group ($P = 0.135$) and was most likely the result of a paralytic ileus that disrupted normal peristaltic activity. The dilated bowel was usually filled with fluid or blood from the ischemic bowel wall. Considering the specificity (93.6%), this feature indicates ischemic bowel wall damage.[27]

Our study has some limitations. First, this study was limited by its retrospective nature. Prospective studies will be necessary to investigate whether the 6 identified CT features are useful in the decision to operate. Second, enhanced CT is usually used to diagnosis BHVI/MI in developed countries. However, there is still controversy about the use of oral and intravenous contrast agents in emergency settings, due to the risks of increasing radiation dose to the community, allergic reaction, liver and kidney toxicity, poor sensitivity, aspiration, false-negative results, and delays in obtaining data.[9,10] Our hospital is located in a less-developed area of China, where many patients cannot afford costly enhanced CT scans. These considerations, in part, underlie the rationale for using CT scans without oral or intravenous contrast in the trauma setting. According to our findings, unenhanced CT is comparable to contrast-enhanced CT in the ability to diagnose BHVI/MI. Third, this study did not include conservative patients who may have presented with some of the CT features seen in the BHVI/MI group. This exclusion limits the potential of this study to determine the accuracy of CT to diagnose BHVI/MI. However, as our main goal was to examine CT findings in patients with BHVI/MI confirmed by laparotomy, this exclusion criterion was necessary. Fourth, we did not evaluate the effect of time between CT and laparotomy. Some studies have shown that shorter time intervals result in better comparisons between CT and surgery.[1] Further studies are needed to address these issues.

CONCLUSIONS

This study demonstrates that unenhanced CT is valuable for diagnosing BHVI/MI in an emergency setting. Six significant CT signs that contributed to the diagnosis of BHVI/MI were identified, including intra- or retro-peritoneal air, bowel wall thickening, mesentery thickening, mesenteric fat infiltration, peritoneal fat infiltration, and parietal peritoneum thickening.

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