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PICTORIAL ESSAYS

Blunt bowel and mesenteric injury: MDCT diagnosis

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Abstract

Multidetector computed tomography (MDCT) has emerged as the imaging modality of choice for evaluating the abdomen and pelvis in trauma patients. MDCT readily detects injury of the solid organs as well as direct and indirect features of bowel and/or mesenteric injury—an important advance given that unrecognized bowel and mesenteric injuries may result in high morbidity and mortality. Nonetheless, challenges persist in the interpretation of abdominal and pelvic CT images in trauma patients. Difficulty in interpretation may result from lack of familiarity with or misunderstanding of CT features of bowel and/or mesenteric injury. Moreover, due to major technical advances afforded by MDCT, new CT features of bowel and/or mesenteric injuries have been recognized. Beading and termination of mesenteric vessels indicating surgically important mesenteric injury is an example of one of these new features. MDCT also allows for the detection of small or trace amounts of isolated intraperitoneal fluid in trauma patients, although the clinical management of these patients is still controversial. This pictorial essay illustrates the spectrum of typical, atypical, and newly reported MDCT features of bowel and mesenteric injuries due to blunt trauma. The features that help to differentiate these injuries from pitfalls are emphasized in these proven cases.

Key words: Bowel and mesenteric injury—Multidetector computed tomography—CT features—Free fluid—Pitfalls

Injury to the bowel and/or mesentery after blunt trauma is uncommon, estimated to occur in 1–5% of cases [1–3]. The consequences of missed injury are significant, resulting in increased morbidity and mortality. Since the clinical signs of these injuries often are not specific or may be delayed in presentation, various diagnostic tests, including peritoneal lavage, ultrasonography (US), and computed tomography (CT) have been used in the evaluation of blunt trauma patients. Diagnostic peritoneal lavage is neither specific nor sensitive; bowel perforation may be missed at lavage in up to 10% of cases [4]. Focused assessment with US in the trauma setting yields a sensitivity of 86% for the detection of free intraabdominal fluid, but it is nonspecific with regard to organ injury [5].

For many years, the accuracy of computed tomography in detecting injury of the bowel or mesentery has been questioned [6, 7]. Most of the studies that questioned the accuracy of CT were performed with earlier generation CT scanners and involved small numbers of patients. Owing to major technical advances in CT in general and the advent of multidetector computed tomography (MDCT) in particular, the accuracy of the CT diagnosis of bowel and mesenteric injuries has improved and CT has become the imaging modality of choice for evaluation of the abdomen and pelvis following trauma [8–17]. Features of bowel and/or mesenteric injury at MDCT include free fluid, free air, oral contrast extravasation, bowel wall thickening and abnormal enhancement, bowel wall defect, intramural air, mesenteric infiltration and hematoma, intravenous extravasation from mesenteric vessels, and beading or abrupt termination of mesenteric vessels.

Not all bowel and/or mesenteric injuries require surgical intervention [16]. Surgically important injuries include a complete tear of the bowel, serosomuscular tear, devascularized bowel, active mesenteric bleeding, and mesenteric injury associated with bowel ischemia. In

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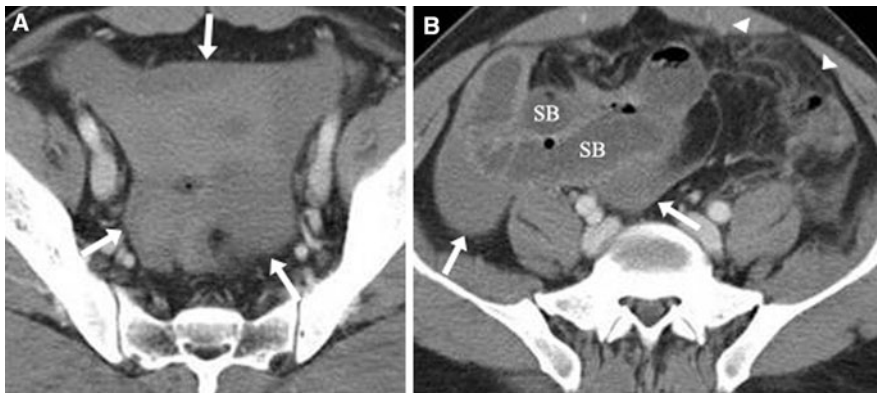

Fig. 1. A 32-year-old male status post-blunt abdominal trauma. **A** Axial contrast-enhanced CT of the pelvis demonstrated a large amount of free fluid (*arrows*) in the absence of solid organ injury. **B** Axial contrast-enhanced CT of the upper pelvis demonstrated a moderate amount of fluid (*arrows*) surrounding loops of normal-appearing small bowel (*SB*) in the right lower quadrant. Fat stranding (*arrowheads*) was noted in the omentum. Surgery confirmed avulsed segment of the distal ileum.

Fig. 2. A 60-year-old male status post-blunt abdominal trauma. **A** Axial contrast-enhanced CT of the abdomen demonstrated a hematoma (*arrows*) in the mesentery of the descending colon (*C*). **B** Axial contrast-enhanced CT of the deep pelvis showed no free fluid (*arrow*). Bladder (*B*) was noted. Surgery revealed a mesenteric hematoma that did not require repair.

contrast, injuries that do not require surgical intervention include a tear limited to the serosa, bowel wall hematoma without a full thickness tear, and an isolated mesenteric hematoma.

This pictorial essay illustrates common, uncommon, and newly identified MDCT findings of bowel and mesenteric injury following blunt abdominal trauma. The features that help to differentiate these findings from interpretive pitfalls are emphasized in these proven cases.

Patients, MDCT studies, and interpretation of images

For a 3-year period (2004–2006), patients ($n = 26$) with surgically proven blunt bowel and/or mesenteric injury and with a preoperative contrast material enhanced MDCT were identified from the trauma registry of our level-1 trauma center. All 26 CT examinations were acquired in a multidetector helical CT scanner (Somatom Plus 4 Volume Zoom; Siemens Medical Systems, Erlangen, Germany) with reconstructed axial images at a section thickness of 5 mm for review. A 70-s delayed portal

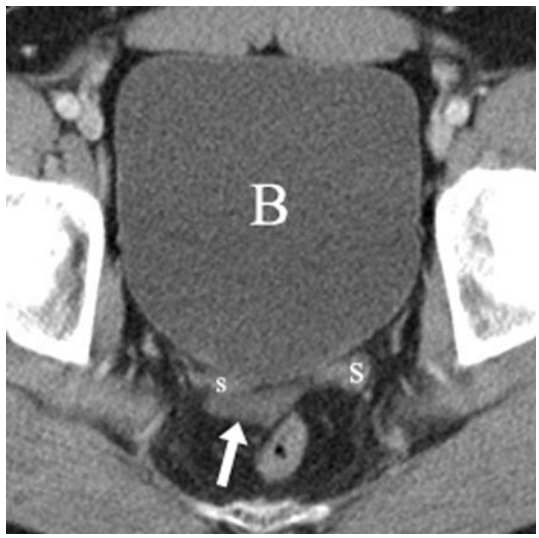

Fig. 3. A 28-year-old male status post-blunt abdominal trauma. Contrast-enhanced CT of the pelvis demonstrated a small amount of free fluid (*arrow*) posterior to the seminal vesicles (*S*). Bladder (*B*) is noted. Surgery was not performed. Chart review revealed that the patient did not present with bowel and/or mesenteric injury during the 2 weeks of clinical follow-up.

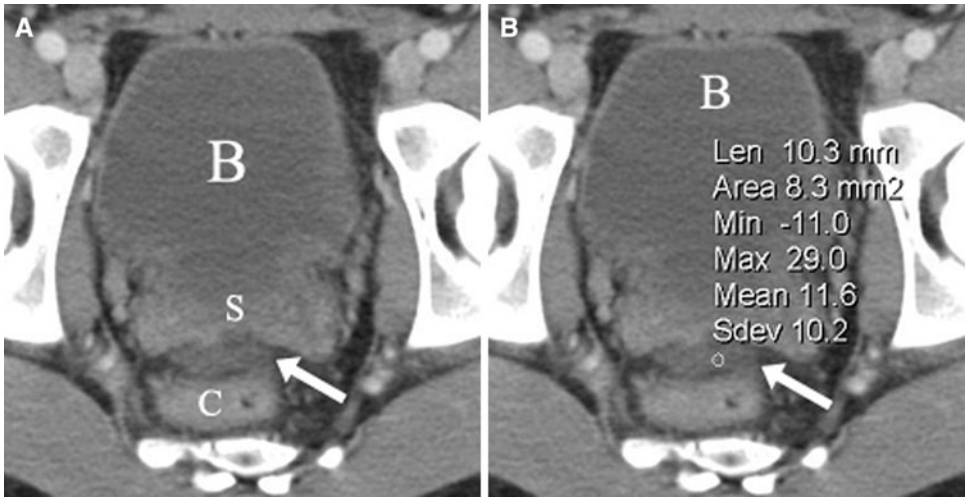

Fig. 4. A 34-year-old male status post-blunt abdominal trauma. **A** Contrast-enhanced CT of the pelvis demonstrated a small amount of free fluid (*arrow*) posterior to the seminal vesicle (*S*) and anterior to the rectum (*C*). Bladder (*B*) is noted**. B** Contrast-enhanced CT of the deep pelvis demonstrated the small amount of free fluid (*arrow*) seen on (**A**) with attenuation 11.6 HU. Bladder (*B*) is noted. Chart review revealed that the patient did not have bowel and/or mesenteric injury during the 2 weeks of clinical follow-up.

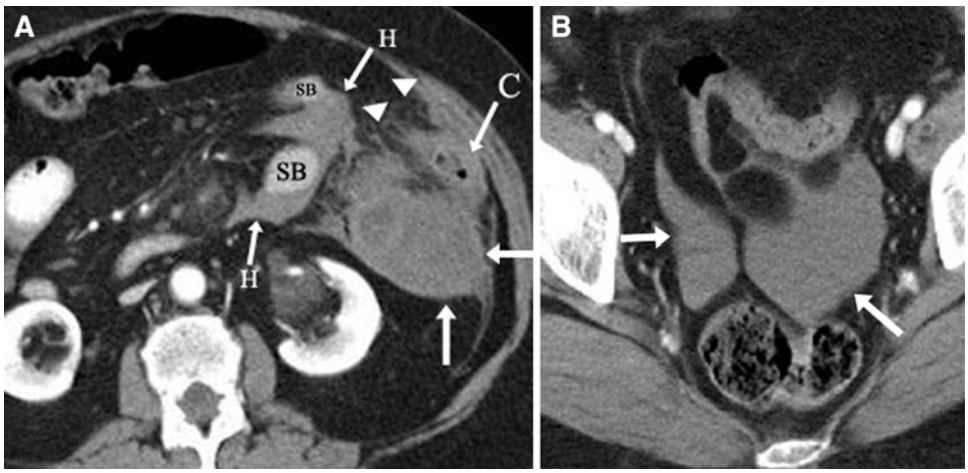

Fig. 5. A 64-year-old female status post-blunt abdominal trauma. **A** Axial contrast-enhanced CT of abdomen demonstrated thickened descending colonic wall (*C*) with pericolonic fat stranding (*arrowheads*) and with an adjacent large fluid collection (*arrows*) in the left anterior pararenal space. Triangular shaped hematomas (*H*) were noted between loops of small bowel (*SB*). **B** Axial contrast-enhanced CT of the pelvis demonstrated a moderate attenuation of free fluid (*arrows*) with attenuation 27 HU. Surgery confirmed perforation of the descending colon.

venous phase was obtained for all CT examinations with an injection rate of 2–3 mL/s. All but two patients received oral contrast material before the CT scan.

Two experienced abdominal radiologists reviewed all CTs retrospectively for signs of bowel and/or mesenteric injury. The signs identified during the review were correlated with surgical findings. There were 21 patients with surgically proven primary bowel injuries and 15 patients with mesenteric injuries. With respect to the location of bowel injuries, 1 (4.8%) patient had injury to the stomach; 12 (57.1%) patients had injuries to the small bowel; 6 (28.5%) patients had injury to the large bowel; and 2 (9.6%) patients had injury to multiple sites. Twenty-two of twenty-six patients had surgically important injuries to the bowel and/or mesentery. The remaining 4 of 26 patients had nonsurgically important bowel and/or mesenteric injury; serosal tear of bowel ($n = 3$) and mesenteric hematoma without active bleeding ($n = 1$).

Controversy exists regarding the use of oral contrast material in trauma patients. Some authors assert that oral contrast material is safe and improves visualization of bowel injuries [13, 18], while others claim that oral contrast material increases the risk of vomiting and aspiration without improvement of diagnostic capability

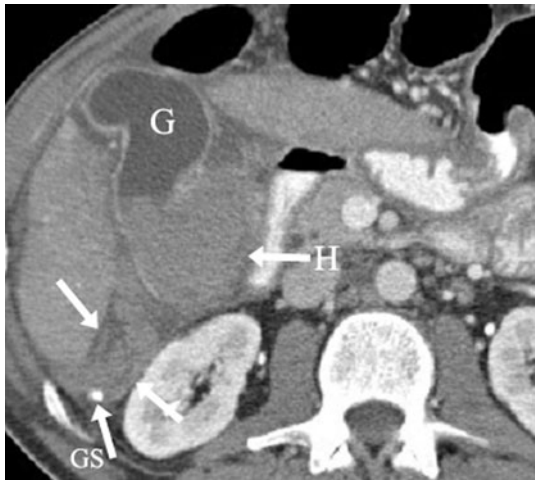

Fig. 6. A 45-year-old female status post-blunt abdominal trauma. Axial contrast-enhanced CT of the abdomen demonstrated a moderate amount of hemorrhage (*arrows*) adjacent to the distended gallbladder (*G*) which contained hemorrhage in the dependent portion (*H*). An extruded gallstone (*GS*) was noted in the fluid collection. Rupture of the gallbladder was noted at surgery but no bowel or mesenteric injury was identified.

[7, 15]. At our level-1 trauma center, oral contrast material (barium or gastrografin) is usually given if tolerated by the patient. Oral contrast material proves helpful in the detection and confirmation of bowel wall thickening, distinction of bowel from hemoperitoneum, and diagnosis of oral contrast extravasation.

MDCT features of bowel and/or mesenteric injury

Features of bowel and mesenteric injury

Intraperitoneal and retroperitoneal fluid. The presence of free fluid is one of the most sensitive and important CT features of bowel and/or mesenteric injuries [19, 20]. The fluid may be of low attenuation, representing extravasated bowel contents, or of intermediate to high attenuation due to acute hemorrhage or oral contrast material extravasation. Brofman et al. [11] reported that 93% of patients with bowel and/or mesenteric injury had free fluid. Without visible solid organ injury, the presence of a moderate or large amount of free fluid is a strong indicator for exploratory laparotomy [21] (Fig. 1). On

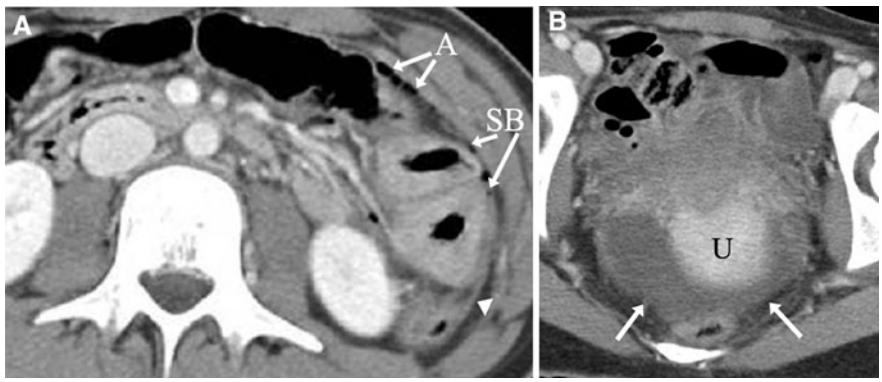

Fig. 7. An 18-year-old female status post-blunt abdominal trauma. **A** Axial contrast-enhanced CT of the abdomen demonstrated wall thickening of small bowel loops (*SB*) in the left abdomen with adjacent fat stranding (*arrowhead*) and free air (*A*). **B** Axial contrast-enhanced CT of the pelvis demonstrated a moderate amount of free fluid (*arrows*) with attenuation 22 HU adjacent to the uterus (*U*). Surgery confirmed perforation of the jejunum.

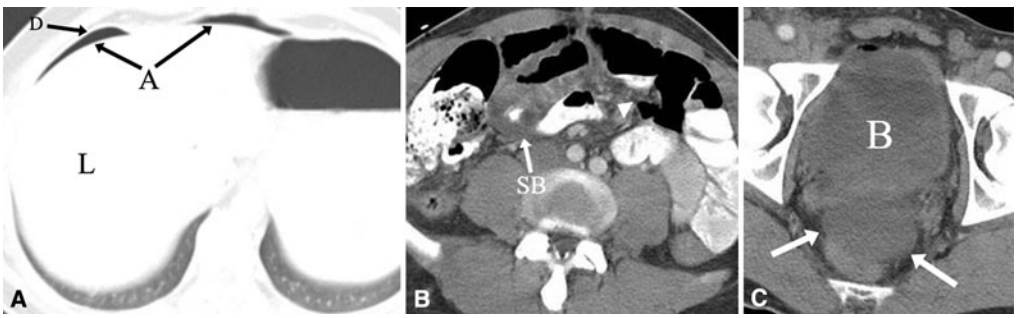

Fig. 8. A 25-year-old male status post-blunt abdominal trauma. **A** Axial CT of the abdomen in a lung window demonstrated a small amount of free air anterior to the liver (*L*) and below the diaphragm (*D*). **B** Axial contrast-enhanced CT of the upper pelvis demonstrated a loop of small bowel with wall thickening (*SB*). **C** Axial contrast-enhanced CT of the pelvis demonstrated a moderate amount of free fluid (*arrows*) with attenuation 26 HU. Bladder (*B*) is labeled. Perforation of the ileum was found at surgery.

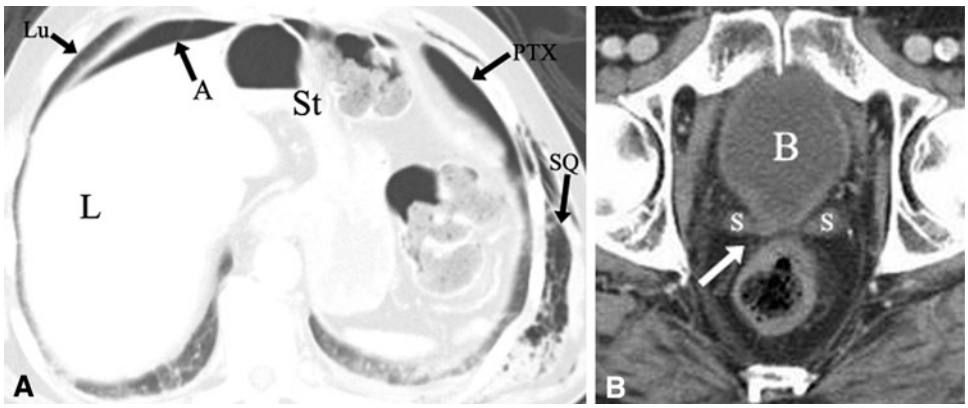

Fig. 9. A 70-year-old male status post-blunt abdominal trauma. **A** Axial CT of the lower chest in a lung window demonstrated a small amount of free air (*A*) anterior to the liver (*L*) and posterior to the lung (*Lu*). Left pneumothorax (*PTX*), subcutaneous emphysema (*SQ*), and stomach (*St*) were noted**. B** Axial contrast-enhanced CT of the deep pelvis showed no free fluid (*arrow*). Bladder (*B*) and seminal vesicles (*S*) are labeled. Chart review revealed that the patient did not have bowel and/or mesenteric injury.

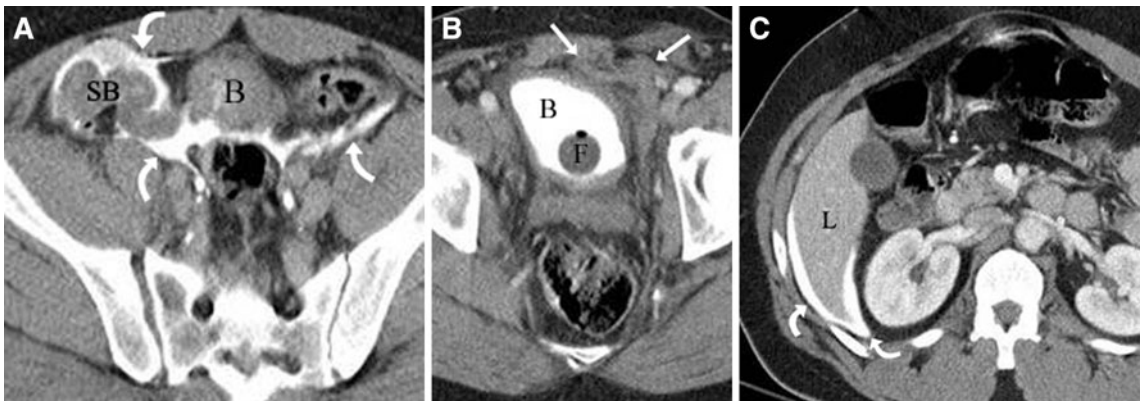

Fig. 10. A 58-year-old male status post-blunt abdominal trauma. **A** Axial contrast-enhanced CT of the upper pelvis demonstrated contrast material (*curved arrows*) adjacent to the bladder (*B*) and surrounding a loop of small bowel (*SB*) in the right lower quadrant**. B** Axial contrast-enhanced CT of the pelvis demonstrated bladder (*B*) containing contrast material. A small amount of fluid (*arrows*) was noted anteriorly to the bladder**. C** Axial contrast-enhanced CT of the abdomen demonstrated extravasated contrast material (*curved arrows*) outlining the liver (*L*). Intraperitoneal rupture of the bladder was confirmed at surgery.

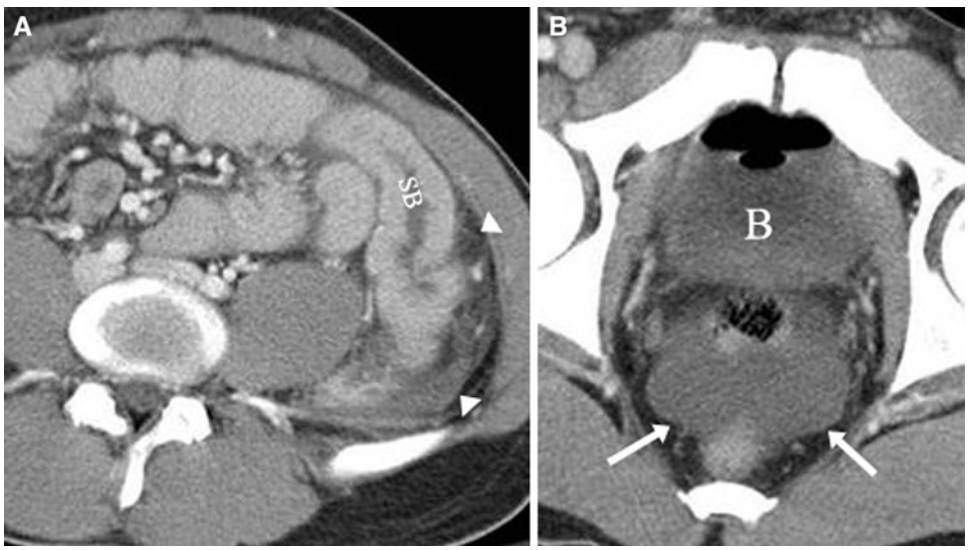

Fig. 11. A 20-year-old male status post-blunt abdominal injury. **A** Axial contrast-enhanced CT of the abdomen demonstrated wall thickening of a small bowel loop (*SB*) in the left abdomen with adjacent fat stranding (*arrowheads*)**. B** Axial contrast-enhanced CT of the pelvis demonstrated a moderate amount of free fluid (*arrows*) with attenuation 26 HU. Bladder (*B*) is noted. Jejunal perforation was identified at surgery.

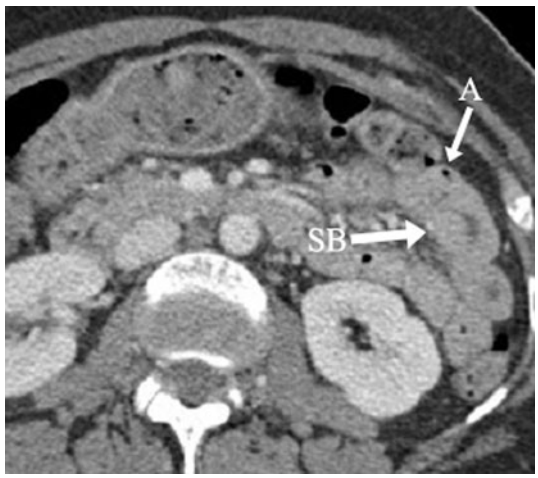

Fig. 12. A 43-year-old female status post-blunt abdominal trauma. Axial contrast-enhanced CT of the abdomen demonstrated a loop of small bowel (*SB*) with apparent wall thickening. However, in the nondependent portion of the bowel, there was an air locule demarcating the thin wall of the bowel (*A*). Therefore, the loop of small bowel has a normal wall thickness.

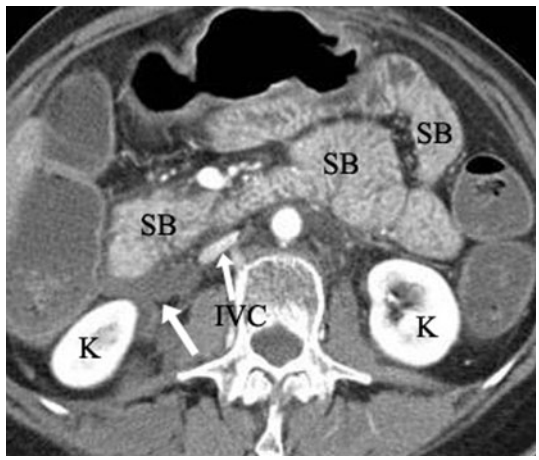

Fig. 14. A 58-year-old male status post-blunt abdominal trauma. Axial contrast-enhanced CT of the abdomen demonstrated loops of small bowel (*SB*) with pronounced mucosal enhancement. A small amount of free fluid (*arrow*), flattened inferior vena cava (*IVC*) and increased enhancement of kidneys (*K*) were noted. Findings are consistent with shock bowel secondary to hypotension. Chart review confirmed that the patient had cervical spine injury without bowel injury.

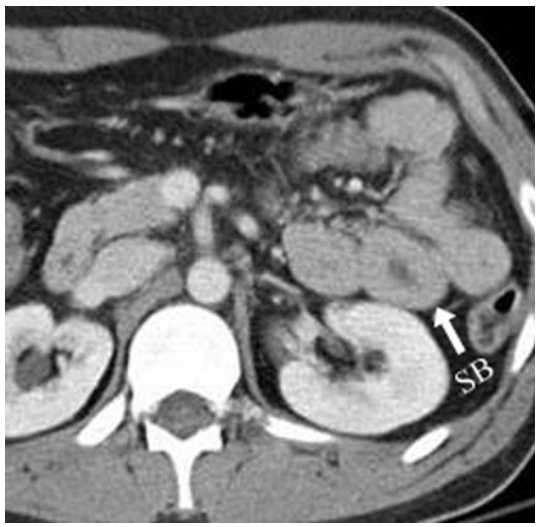

Fig. 13. A 21-year-old male status post-blunt abdominal trauma. Axial contrast-enhanced CT of the abdomen demonstrated a loop of small bowel (*SB*) with apparent wall thickening. Chart review revealed that the patient did not have bowel injury. This finding was due to incomplete mixing of oral contrast material and bowel contents.

Fig. 15. A 23-year-old male status post-blunt abdominal trauma. Axial contrast-enhanced CT of the abdomen demonstrated bowel wall defect (*open arrows*) of a loop of small bowel (*SB*) surrounded by a large hematoma in the mesentery (*arrows*). Active bleeding (*double arrows*) within the mesenteric hematoma was noted. Surgery confirmed jejunal perforation and active bleeding in the mesentery.

the other hand, in a patient with blunt abdominal trauma and without intraperitoneal fluid, a surgically important bowel and/or mesenteric injury is practically excluded [16] (Fig. 2).

Owing to marked improvement in spatial resolution, scanning speed and the ability to acquire submillimeter images, MDCT detects isolated, small amounts of pelvic free fluid in a number of blunt trauma patients. Small amount of isolated pelvic free fluid in a female trauma patient is usually considered physiologic in nature. On the other hand, for many years, radiologists and surgeons have been taught that any free fluid in a male trauma patient is abnormal, and exploratory laparotomy

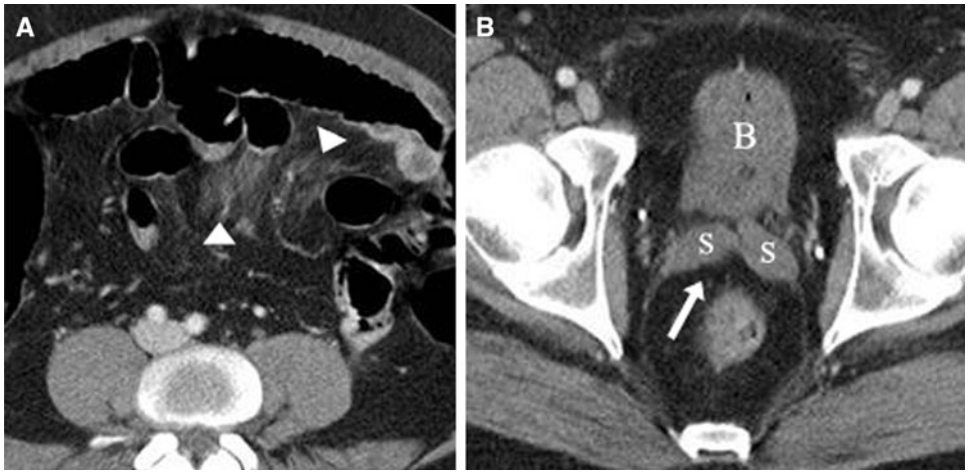

Fig. 16. A 50-year-old male status post-blunt abdominal trauma. **A** Axial contrast-enhanced CT of the abdomen demonstrated fat stranding (*arrowheads*) in the mesentery. **B** Axial contrast-enhanced CT of the pelvis demonstrated no free fluid (*arrow*). Bladder (*B*) and seminal vesicles (*S*) are noted. Surgery was not performed. Chart review confirmed that the patient did not have surgically important mesenteric injury.

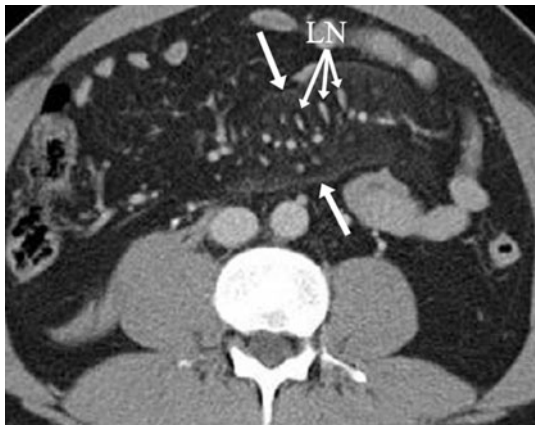

Fig. 17. A 37-year-old male status post-blunt abdominal trauma. Axial contrast-enhanced CT of the abdomen demonstrated well-defined fat stranding (*arrows*), and flat lymph nodes (*LN*) in the mesentery. Chart review revealed that the patient did not have bowel and/or mesenteric injury. CT findings are consistent with mesenteric panniculitis.

is often mandated [22–25]. Recently, Drasin et al. [17] reported that 19 of 669 (2.8%) male trauma patients had isolated intraperitoneal free fluid at 64 MDCT and none of them required surgical intervention. We conducted a study to determine the incidence and significance of a small amount of isolated pelvic free fluid in male blunt trauma patients [26]. We found 4.9% (49 of 1000) of male blunt trauma patients had isolated pelvic free fluid and none of them had bowel and/or mesenteric injury (Fig. 3). It is important to emphasize that in order to be certain that the free fluid in a male blunt trauma patient is not the result of bowel and/or mesenteric injury, the fluid must be isolated (i.e., no imaging findings of trauma), small in amount (fewer than 5 contiguous 5-mm sections), equal to simple fluid in attenuation and located in the deep pelvis (Fig. 4).

Location of the fluid may help in diagnosing the site of bowel and/or mesenteric injury, particularly when fluid is in the retroperitoneum. Fluid collection adjacent to the duodenum, ascending colon, and descending colon is a fairly specific sign of injury and site of injury because retroperitoneal fluid is restricted and tends to localize at the site of injury (Fig. 5). In contrast, intraperitoneal fluid can flow freely in the peritoneal cavity into the most dependant spaces such as the deep pelvis where fluid from bowel and/or mesenteric injury is likely to accumulate. Fluid in the mesentery with a polygonal shape is more likely related to bowel and/or mesenteric injury rather than solid organ injury [27] (Fig. 5A). Occasionally, fluid located in the mesentery or between loops of bowel may be the only CT sign of bowel injury [28].

Diagnostic peritoneal lavage fluid, urine, bile, pancreatic juice, or preexisting ascites in the intraperitoneum or extraperitoneum may mimic the fluid seen in bowel and/or mesenteric injury, thereby creating a diagnostic challenge. In addition to free peritoneal fluid, fluid located adjacent to any organ such as the gallbladder, pancreas, or bladder may indicate injury to the adjacent organ (Fig. 6) rather than to the bowel or mesentery.

Features of bowel injury

Extraluminal air. Free air in either the peritoneal cavity or the retroperitoneum is a relatively specific sign of bowel perforation but is seen in only 20–55% of patients [8, 11, 16, 20]. Six of twenty-six patients (23%) in our study had free air (Fig. 7). In most patients with full-thickness bowel injury, free air is not observed on CT scans at admission [23], which may be secondary to the small volume of air. In some cases, small amounts of free air are overlooked. Therefore, CT images should be viewed at wide window settings (i.e., lung or bone windows) in order to optimize detection of free air (Fig. 8).

Air from a bowel rupture usually localizes posterior to the anterior abdominal wall, in the immediate subdiaphragmatic area, and along the anterior peritoneal surfaces of the liver and spleen (Figs. 7, 8). Foci of air

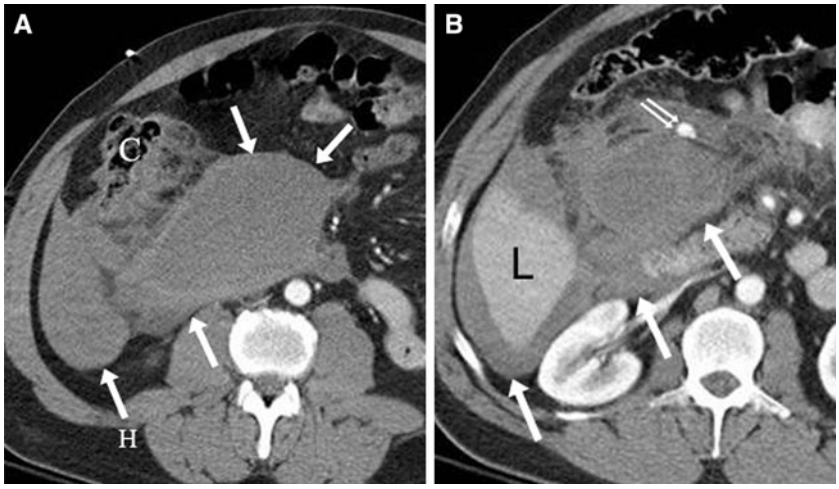

Fig. 18. A 68-year-old male status post-blunt abdominal trauma. **A** Axial contrast-enhanced CT of the abdomen demonstrated a thickened right colonic wall (*C*) with a large adjacent hematoma (*arrows*). A hematoma (*H*) in the right paracolic gutter was noted. **B** Axial contrast-enhanced CT of the abdomen demonstrated active bleeding (*double arrows*) within a large mesenteric hematoma (*arrows*) in the right abdomen. Liver (*L*) is noted. A large mesenteric hematoma with active bleeding and right colonic injury were found at surgery.

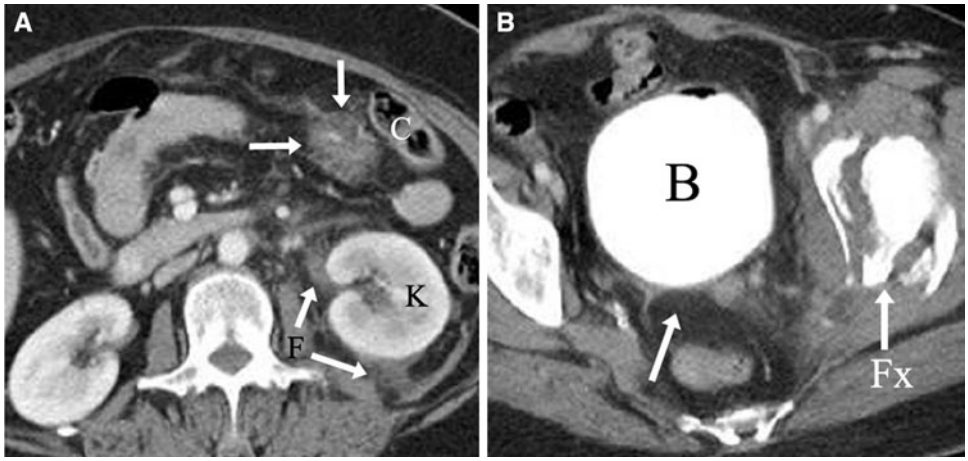

Fig. 19. A 61-year-old male status post-blunt abdominal trauma. **A** Axial contrast-enhanced CT of the abdomen demonstrated a hematoma in the mesentery (*arrows*) near the distal transverse colon (*C*). Left kidney (*K*) with a small amount of perinephric fluid (*arrows*) was noted. **B** Axial contrast-enhanced CT of the deep pelvis demonstrated no free fluid (*arrow*). Bladder filled with contrast material (*B*) was noted. A comminuted fracture (*Fx*) of the right acetabulum was noted. Chart review revealed that the hematoma in the mesentery did not need surgical treatment.

may also be seen in the portal hepatis, mesentery or mesenteric veins, and portal vein. At times, air in the peritoneum or retroperitoneum is not related to bowel injury but results from caudad dissection of air from traumatic injuries of the thorax (Fig. 9), mechanical ventilation, bladder rupture with Foley catheter placement, or peritoneal lavage prior to CT. When foci of free air are seen adjacent to a thickened bowel loop or in association with mesenteric fat stranding or extraluminal fluid, the probability of bowel injury is increased [23] (Figs. 7, 8). Alternatively, if free air is an isolated finding in the abdomen of a trauma patient, causes of free air such as thoracic injury should also be considered.

Oral contrast extravasation. Extravasation of oral contrast from the bowel lumen is a specific sign of bowel perforation but is seen in only a minority of cases [16, 20]. The low sensitivity of this finding may be due to scanning before oral contrast has reached the site of bowel perforation or due to dilution of the small amount of extravasated oral contrast into the larger amount of intraperitoneal free fluid. When there is intraperitoneal

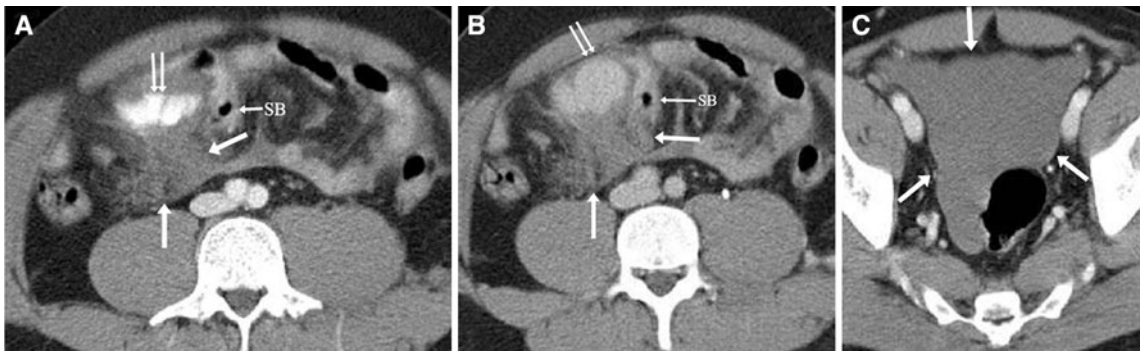

Fig. 20. A 30-year-old male status post-blunt abdominal trauma. **A** Axial contrast-enhanced CT of the abdomen demonstrated active bleeding (*double arrows*) within a mesenteric hematoma (*arrows*). Adjacent small bowel (*SB*) is noted. **B** Delayed axial CT of the abdomen demonstrated increase in size and decrease in attenuation of the active bleeding (*double arrows*) within the hematoma in the mesentery (*arrows*) compared with the initial acquisition images. Adjacent small bowel (*SB*) is noted. **C** Axial contrast-enhanced CT of the deep pelvis demonstrated a large amount of free fluid in the pelvis (*arrows*) with attenuation 37 HU. Mesenteric hematoma with active bleeding was found at surgery.

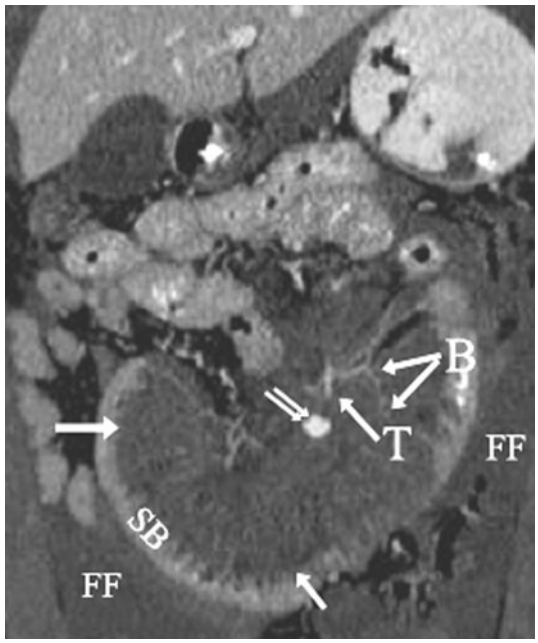

Fig. 21. A 24-year-old male status post-blunt abdominal trauma. Coronal reformatted CT image of the abdomen with intravenous contrast material demonstrated abrupt termination (*T*) and beading (*B*) of jejunal branches of the superior mesenteric artery. A large hematoma in the mesentery (*arrows*) with active bleeding (*double arrows*) was noted and was surrounded by a loop of small bowel (*SB*). Diffuse free fluid (*FF*) in the abdomen was noted. At surgery, a large mesenteric hematoma with active bleeding and perforation of jejunum were found.

rupture of the bladder, extravasated contrast from the bladder may mimic oral contrast extravasation from perforated bowel [11] (Fig. 10). The key differences are that the contrast extravasation from the ruptured bladder occurs only on the delayed images when the bladder is filled with contrast and usually is higher in attenuation than that of extravasated oral contrast.

Bowel wall thickening and abnormal enhancement. Bowel wall thickening is seen in 45–75% of transmural injuries [9, 16]. It was seen in 12 of 21 (57%) patients with primary bowel injury in our study. The injured bowel may demonstrate circumferential or eccentric wall thickening, often with associated luminal narrowing (Fig. 11). However, this finding can be artifactual in nature secondary to underdistention. In general, large bowel wall thickening is more specific for bowel injury [16] (Fig. 5). If a small amount of air outlines a thin wall of the nondependent portion of bowel, even if the dependent portion of bowel appears thickened, the bowel should be considered normal in thickness (Fig. 12). Sometimes, oral contrast material is poorly mixed with bowel contents so that less opacified bowel contents flow into the center of the bowel lumen and the higher attenuation mixture flows peripherally within the bowel mimicking bowel wall thickening (Fig. 13). In the absence of other CT signs of bowel injury such as fat stranding in the adjacent mesentery or free fluid in the abdomen or in the pelvis, this finding alone should raise the possibility of incomplete mixing of oral contrast material.

Increased contrast enhancement of the bowel wall is not a specific sign of bowel injury. This finding can also be seen in trauma patients with prolonged hypoperfusion resulting in shock bowel [9, 11, 29] (Fig. 14). A possible explanation is increased vascular permeability resulting in interstitial leakage of contrast material [29]. Homogeneous mucosal enhancement in a long segment of bowel seen in association with a flattened inferior vena cava and increased enhancement of adrenal glands

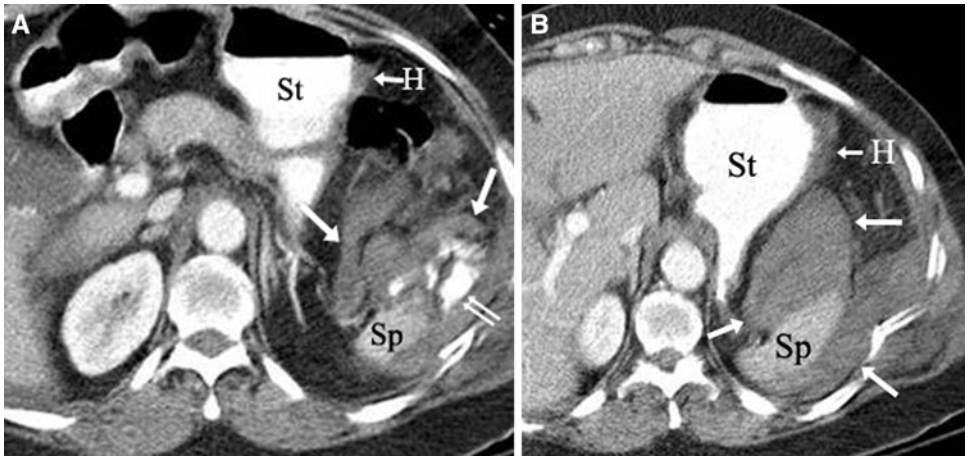

Fig. 22. A 68-year-old male status post-blunt abdominal trauma. **A** Axial contrast-enhanced CT of the abdomen demonstrated a shattered spleen (*Sp*) with active bleeding (*double arrows*) and a large perisplenic hematoma (*arrows*). A small hematoma (*H*) of the gastric wall (*St*) was overlooked. **B** Axial contrast-enhanced CT of the abdomen demonstrated a small hematoma (*H*) of the gastric wall (*St*) which was overlooked initially. A large hematoma (*arrows*) surrounding the spleen (*Sp*) was noted. At surgery, gastric perforation at the site of the hematoma and shattered spleen with active bleeding were identified.

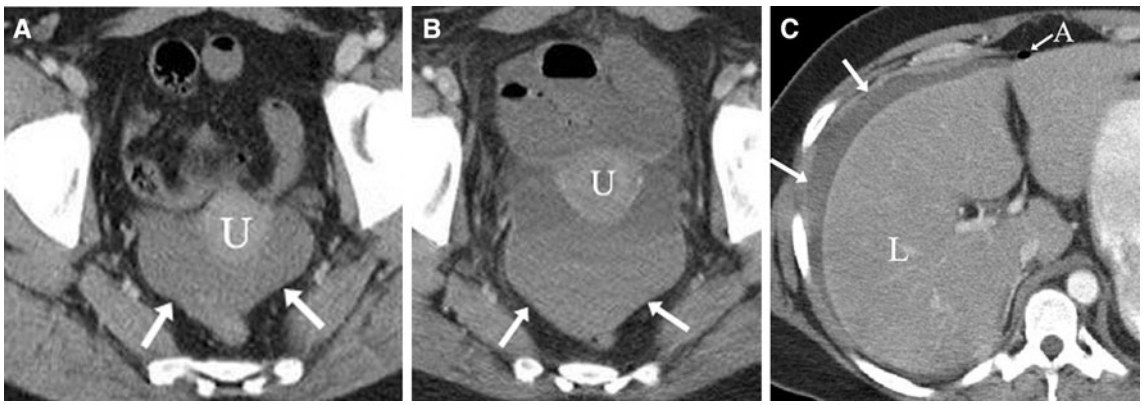

Fig. 23. A 42-year-old female status post-blunt abdominal trauma. **A** Axial contrast-enhanced CT of the pelvis demonstrated a moderate amount of isolated free fluid (*arrows*) adjacent to the uterus (*U*) with attenuation 41 HU. No other CT features of abdominal organ injury were identified (not shown). **B** Axial contrast-enhanced CT of the deep pelvis 23 h after the first CT (**A**) demonstrated increased amount of free fluid (*arrows*) adjacent to the uterus (*U*) with attenuation 47 HU. **C** Axial contrast-enhanced CT of the abdomen 23 h after the first CT (**A**) demonstrated a moderate amount of perihepatic fluid (*arrows*). A new finding of an air locule anterior to the liver (*L*) was noted. Ileal perforation was found at surgery.

and kidneys is suggestive of shock bowel (Fig. 14). In contrast, patchy or irregular increase in bowel wall enhancement in a relatively short segment of bowel is suggestive of bowel injury and is very uncommon [10]. Occasionally, injured bowel may present as lack of wall enhancement [11].

Bowel wall defect. Bowel wall defect has a low sensitivity but a high specificity for bowel injury at CT [30] (Fig. 15). The infrequency of this CT feature is likely secondary to the small size of the defect.

Intramural air. Intramural air is a very uncommon CT feature of bowel injury [8, 9]. This finding may indicate that the injury to the bowel wall is full thickness requiring surgical management.

Features of mesenteric injury

Mesenteric infiltration. A small amount of hemorrhage in the mesentery may result in ill-defined, streaky infiltration of the mesenteric fat (Fig. 16). This finding is very sensitive for mesenteric injury with or without bowel

injury, but is nonspecific. Pre-existing mesenteric stranding from an inflammatory condition such as panniculitis may mimic mesenteric injury in a trauma patient. The key difference between mesenteric panniculitis and mesenteric injury is that the fat stranding in panniculitis is well defined and is associated with multiple flat lymph nodes (Fig. 17).

Mesenteric hematoma. A larger amount of hemorrhage in the mesentery will form a hematoma that sometimes may exert mass effect on adjacent bowel loops. This finding is specific for mesenteric injury, but it does not always indicate a need for surgery. The presence of a mesenteric hematoma should prompt a careful search for any evidence of bowel injury. Bowel wall thickening associated with mesenteric hematoma or fat infiltration indicates a high likelihood of a mesenteric and bowel injury requiring surgery [31] (Fig. 18). On the other hand, an isolated mesenteric hematoma without evidence of active bleeding or free intraperitoneal fluid indicates that the injury is likely not surgically important [11] (Fig. 19). Interloop hemorrhage has been shown to be an unusual feature of solid organ injury and is considered to be more specific for bowel and/or mesenteric injury [32] (Fig. 5).

Mesenteric extravasation. Active mesenteric bleeding appears as high density contrast material surrounded by lower attenuation hematoma (Fig. 18), and was seen in 5 of 26 (19%) of our patients. This feature has 100% specificity for the diagnosis of significant mesenteric injury and often indicates a need for urgent laparotomy. The areas of extravasation range in attenuation from 80 to 370 HU, and usually have attenuation within 10 HU of an adjacent contrast-enhanced artery. Delayed images often demonstrate increase in size and decrease in attenuation of active bleeding (Fig. 20). With a higher spatial resolution and faster data acquisition by MDCT, detection of active bleeding sites in blunt abdominal trauma patients is becoming more common.

Beading and termination of mesenteric vessels. At MDCT, beading of mesenteric vessels is defined as an irregularity of mesenteric vessels and termination of mesenteric vessels indicates abrupt cutoff of a mesenteric artery or vein (Fig. 21). Both CT features are indicative of significant mesenteric injury with specificity ranging from 93% to 95%. However, the sensitivity of both features is relatively low ranging from 45% to 50% [11, 16]. Due to the orientation of the mesenteric vessels, these CT signs are better appreciated on coronal or sagittal reformatted images (Fig. 21).

Bowel and/or mesenteric injury coexisting with other abdominal injuries

When bowel and/or mesenteric injury occurs in conjunction with other abdominal injuries such as splenic or liver laceration, the CT signs of bowel and/or mesenteric injury may be overlooked or misinterpreted (Fig. 22). When a moderate or large amount of free fluid is encountered in the abdomen or pelvis in a blunt abdominal trauma patient, bowel and/or mesenteric injury is very likely if there is no evidence of solid organ injury. However, if there is solid organ injury, then the fluid in the abdomen and pelvis is often attributed to the injury of solid organs, and the diagnosis of bowel and/or mesenteric injury goes unrecognized. Interloop fluid, as seen in the ''triangle'' sign'' (Fig. 5), has been shown to be unusual with solid organ injury and is considered to be more specific for bowel and/or mesenteric injury [27, 32]. A careful search for any CT sign of bowel and/or mesenteric injury in patients with multiple injuries of abdominal organs will prevent unrecognized cases of concomitant bowel and/or mesenteric injury.

Short-term follow-up CT study following blunt abdominal trauma

In a small group of trauma patients with questionable CT findings, a short-term (6–48 h) follow-up CT may be very helpful in confirming or excluding the diagnosis of bowel and/or mesenteric injury [15] (Fig. 23). The most common interval change is the amount of free fluid. If the injury to the bowel and mesentery is surgically important, the amount of free fluid likely will increase with time. Although short-term imaging follow-up may be beneficial for some patients, it may delay discharge and may expose patients to unnecessary radiation [17].

Conclusions

Most bowel and/or mesenteric injuries are readily detected at MDCT, but others are more subtle and require careful evaluation and interpretation along with experience. A moderate or large amount of intraperitoneal fluid in a blunt abdominal trauma patient without solid organ injury is strongly indicative of bowel and/or mesenteric injury. In contrast, a small or trace amount of isolated pelvic free fluid in the setting of trauma, even in a male patient, likely has no clinical significance.

Foci of free air adjacent to a thickened bowel loop or an area of mesentery fat stranding, or in association with free intraperitoneal fluid, are highly specific findings of bowel injury. Oral contrast extravasation, bowel wall defect, and intramural air have a low sensitivity but a high specificity in the diagnosis of bowel perforation or full thickness of bowel injury. Although thickened bowel wall is a subjective sign of bowel injury, it can be very useful in the diagnosis and localization of the site of injury.

Mesenteric intravenous contrast material extravasation and beading and termination of mesenteric vessels are specific signs of significant mesenteric injury, usually indicating a need for urgent laparotomy. Isolated mes-

enteric hematoma and fat stranding may represent an injury that can be managed without surgery.

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