Multidetector CT of Surgically Proven Blunt Bowel and Mesenteric Injury[1]

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See discussion on this article by Patlas (pp 625–627).

SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Identify and describe the three mechanisms of blunt bowel and mesenteric injury.
- Discuss the sensitivity and specificity of various CT findings of blunt bowel and mesenteric injury.
- Recognize potential pitfalls in the evaluation of patients who are suspected of having blunt bowel and mesenteric injury.

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Blunt traumatic injury is one of the leading causes of morbidity and mortality in the United States. Unintentional injury represents the leading cause of death in the United States for all persons between the ages of 1 and 44 years. In the setting of blunt abdominal trauma, the reported rate of occurrence of bowel and mesenteric injuries ranges from 1% to 5%. Despite the relatively low rate of blunt bowel and mesenteric injury in patients with abdominal and pelvic trauma, delays in diagnosis are associated with increased rates of sepsis, a prolonged course in the intensive care unit, and increased mortality. During the past 2 decades, as multidetector computed tomography (CT) has emerged as an essential tool in emergency radiology, several direct and indirect imaging features have been identified that are associated with blunt bowel and mesenteric injury. The imaging findings in cases of blunt bowel and mesenteric injury can be subtle and may be seen in the setting of multiple complex injuries, such as multiple solid-organ injuries and spinal fractures. Familiarity with the various imaging features of blunt bowel and mesenteric injury, as well as an understanding of their clinical importance with regard to the care of the patient, is essential to making a timely diagnosis. Once radiologists are familiar with the spectrum of findings of blunt bowel and mesenteric injury, they will be able to make timely diagnoses that will lead to improved patient outcomes.

Introduction

Trauma presents a serious public health problem. In the United States, unintentional injury is the leading cause of mortality for all individuals between the ages of 1 and 44 years (1). In 2013, unintentional injuries were the single leading cause of years of potential life lost for this demographic (1). In addition to being a leading cause of mortality, blunt trauma, including falls and transportation-related injuries, accounted for more than 1.2 million nonfatal injuries in 2013 (1).

The patterns of injury in the setting of blunt trauma are well established. The abdomen is the third most commonly injured region in trauma, after the head and extremities (2). Splenic injuries are the most common solid viscus injury in blunt abdominal trauma, but most splenic injuries are managed without surgery (3). Far less common are blunt bowel and mesenteric injuries, which are reportedly found in approximately 1%–5% of patients with blunt abdominal trauma (4–8) and may be a diagnostic challenge for the radiologist. Injuries of the bowel and mesentery in blunt abdominal trauma are relatively uncommon and can be difficult to detect because of the presence of multiple concurrent injuries, injury of multiple bowel segments, and subtle imaging findings. Thus, blunt bowel injuries remain a diagnostic challenge for the radiologist (2,4–6,8–15).

TEACHING POINTS

- In the United States, unintentional injury is the leading cause of mortality for all individuals between the ages of 1 and 44 years.
- The routine use of oral contrast material is not necessary in the CT evaluation of patients with blunt abdominal trauma.
- Isolated free intraperitoneal air is not always due to a perforated bowel and may be caused by pneumothorax, chest tube placement, or diaphragmatic injury. However, free air associated with free fluid, the seat-belt sign, or a focal bowel abnormality is highly predictive of bowel injury.
- Approximately 3% of male patients may have a small amount of low-attenuation simple fluid in the pelvis without an associated intra-abdominal injury.
- The incidence of blunt bowel and mesenteric injury increases substantially as the number of abdominal solid-organ injuries rises. When three abdominal solid organs are injured, the risk for bowel injury is 34%.

Multidetector CT Technique in Blunt Abdominal Trauma

Optimization of computed tomographic (CT) protocols is particularly important in the evaluation of trauma patients. The radiologist must maximize the chance of making an accurate and timely diagnosis for a patient who may be critically ill.

The routine use of oral contrast material is not necessary in the CT evaluation of patients with blunt abdominal trauma (16). In many institutions, administration of oral contrast material has been routine. However, many investigators from multiple institutions have shown that administration of oral contrast material is not necessary in the setting of blunt abdominal trauma (17–23). In the results of a prospective study, Allen et al (17) found that the sensitivity and specificity of multidetector CT without oral contrast material administration were 95.0% and 99.6%, respectively. Stuhlfaut et al (22) found that oral contrast material administration was not necessary to detect blunt bowel and mesenteric injury requiring surgical repair. In the results of a meta-analysis of 32 studies, Lee et al (16) found no difference in the accuracy of CT performed with or without oral contrast material for the detection of blunt bowel and mesenteric injury. In the findings from multiple studies, investigators have demonstrated that oral contrast material administration is not routinely required in the evaluation of patients with blunt abdominal injury.

At our institution, trauma protocols are custom-tailored to the mechanism of injury and the suspected associated injuries. Our dedicated trauma imaging protocol for blunt abdominopelvic trauma consists of either one or two scan sequences. The scanner used at our institution is a 64-detector CT scanner (LightSpeed VCT; GE Healthcare, Milwaukee, Wis).

Initially, contiguous 1.25-mm axial sections are acquired from the lung bases through the greater trochanters during the portal venous phase by using a 70-second delay after the administration of 100 mL of intravenous contrast material. A pitch of 1.375:1 is used for 40-mm detector coverage, with a kilovoltage of 120 kVp and automodulated current ranging between 150 and 650 mAs and a noise index of 23.

After the first CT scan is performed during the portal venous phase, the radiologist reviews the images in real time and decides if additional delayed phase images should be obtained at 5 minutes. The same technical parameters are used. In all cases, reformatted images are also obtained at a 3.75-mm section thickness, as well as in the coronal and sagittal planes (2.5 × 2.5 mm).

Previously, all patients who were scanned in the setting of trauma at our institution underwent a second CT scan at the 5-minute delay after contrast material administration. In an effort to reduce the radiation dose and improve efficiency, patients only undergo a second delayed phase CT scan when an abnormality is detected in real time by the radiologist. For example, a small blush of contrast material in the mesentery may increase substantially on the delayed phase images, illustrating the severity of hemorrhage more clearly. On the contrary, patients in whom the initial CT scan shows entirely normal results are not scanned again and are thus spared the additional radiation dose.

It should be noted that although we do not routinely perform an arterial phase CT scan of the abdomen and pelvis in patients with isolated blunt abdominal trauma, it has been shown that the combination of an arterial phase scan and a portal venous phase scan increases the sensitivity and accuracy for the detection of splenic vascular injury (24–26). However, in patients undergoing CT of the chest, abdomen, and pelvis because of high-velocity mechanisms of blunt trauma (namely, motor vehicle collisions), the arterial phase of the chest CT scan is extended inferiorly to include the splenic vasculature.

Mechanisms of Blunt Bowel and Mesenteric Injury

Motor vehicle collisions are responsible for most cases of blunt bowel and mesenteric injury, and men more commonly present with blunt force abdominal trauma than women (27). Although most cases of blunt bowel and mesenteric injury are seen in the setting of high-speed motor vehicle collisions, there are several mechanisms by which injury to the bowel or mesentery can occur. Specifically, three mechanisms of injury have been described that may result in blunt bowel and mesenteric injury (28). The three types of

described mechanisms of blunt bowel injury are shear, crush, and burst mechanisms.

First, shearing forces can result in injury to the bowel and mesentery because of rapid deceleration. Shearing forces are most pronounced at locations where the bowel is fixed, including the ligament of Treitz, the ileocecal valve, and the sigmoid colon (28). When rapid deceleration occurs, the bowel and mesentery at these fixed locations are more susceptible to bowel lacerations, mesenteric tears, and interruption of the mesenteric vessels. The interruption of the mesenteric blood supply can result in subsequent bowel ischemia and infarction.

The second method of injury is the crush injury, in which the small or large bowel is compressed between an external force and the osseous skeleton. Commonly, the external force is due to a seat belt across the abdomen or an impact against the steering wheel or dashboard in the setting of motor vehicle collisions. Supporting this point is the fact that the incidence of injury to the small bowel and mesentery increased after the introduction of seat belts (29).

The third and final mechanism is the so-called burst injury, which occurs when the intraluminal pressure is increased within loops of bowel, causing perforation. Typically, the perforations caused by this mechanism occur when the intraluminal pressure reaches 120–140 mm Hg, which classically results in either a single perforation or multiple small perforations of the antimesenteric border of the bowel (29). Conditions that predispose patients to this type of bowel injury include ileus, preexisting bowel obstruction, or Crohn disease (29). Unlike the crush and shearing mechanisms of blunt bowel and mesenteric injury described in the preceding paragraphs, burst injuries can occur with relatively less force and therefore are less likely to be associated with other injuries.

Management of Blunt Bowel and Mesenteric Injury

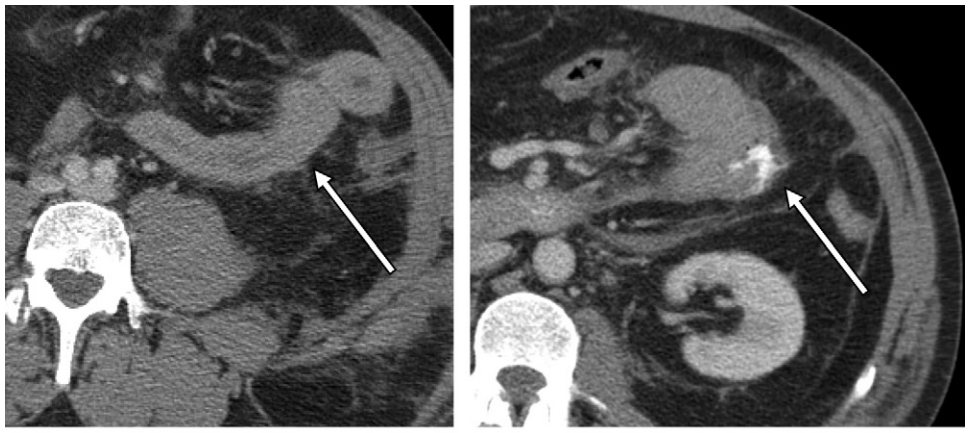
According to the Advanced Trauma Life Support (ATLS) protocol, the first steps in the care of a trauma patient are the identification and treatment of any acute life-threatening injuries (30). The main goals in this acute setting are resuscitation, maintenance of adequate respiratory and circulatory systems, and prevention of disability. Examples of treatment options include intubation, blood transfusions, administration of intravenous fluids, and spinal cord precautions.

After this initial treatment, the trauma specialist is able to perform a more complete physical examination of the patient to determine if emergent surgery is indicated. Often, the findings from physical examination are unreliable in the trauma setting because of confounding factors such as an altered mental status or alcohol intoxication. Therefore, additional tests and procedures are necessary to direct the patient's clinical treatment plan. In a patient whose condition is hemodynamically unstable, assessment for hemoperitoneum is critical. This analysis can be performed with a focused assessment with sonography for trauma or with a more outdated procedure called diagnostic peritoneal lavage (27). A focused assessment with sonography for trauma is used to evaluate the patient's pericardium, the splenorenal and hepatorenal spaces, the bilateral paracolic gutters, and the pouch of Douglas (27). The results of the assessment are considered positive if free fluid is found within any of these spaces.

Once the patient's condition is stabilized, multidetector CT of the abdomen and pelvis is frequently used to further evaluate any inconclusive findings from the focused assessment with sonography for trauma or from the physical examination. Multidetector CT is excellent for detecting solid-organ injuries and can be used to identify the source of hemorrhage in many clinical scenarios. Investigators have shown that multidetector CT is also effective for identifying bowel and mesenteric injuries (31).

For most solid-organ injuries (ie, liver and spleen injuries) caused by blunt force abdominal trauma, nonsurgical management is the standard of care. In contrast, injuries to the bowel and mesentery necessitate surgical intervention with exploratory laparotomy. Indications for exploratory laparotomy include signs of peritonitis, uncontrolled hemorrhage, deterioration of the patient's clinical condition, or substantial hemoperitoneum. Clinical signs that are especially concerning because of their poor outcomes include hypothermia, coagulopathy, and metabolic acidosis (32). If the patient meets the criteria for surgery, therapy with broad-spectrum antibiotics is started to reduce the risk of infection, and the surgeon's primary goal becomes "damage control" (33,34). In damage control surgery, the surgeon's focus is on controlling any hemorrhage and repairing any apparent hollow-organ injuries. After these acute intra-abdominal injuries are treated, the retroperitoneal and pelvic areas are inspected for injury. If there is clinical concern for intra-abdominal contamination with enteric contents, therapy with broad-spectrum antibiotics is continued for at least 5–7 days. Within 24 hours after the initial surgery, repeat surgery is often performed to further treat any intra-abdominal injuries that were originally left untouched (34).

Recently, work has been done in an attempt to provide better triage of patients who are suspected of having bowel and mesenteric injury. McNutt et al (35) have used a novel scoring



a. b.

Figure 1. Discontinuous bowel wall in a 50-year-old man who sustained blunt abdominal trauma in a boating accident. **(a)** Axial contrast material–enhanced CT image through the abdomen (**a** obtained at a lower level than **b**) shows thickened loops of jejunum (arrow). **(b)** Axial contrast-enhanced CT image shows a small area of bowel wall discontinuity in the mid jejunum, with leakage of oral contrast material (arrow). A splenic laceration and hyperattenuating free fluid in the pelvis were also seen (not shown). At laparotomy, a small-bowel perforation was confirmed that required resection. A left hemicolectomy was also performed, and a cecal tear required primary repair.

system, consisting of the bowel injury prediction score, to triage patients who are suspected of having bowel injury. One point each was awarded for leukocytosis of more than 17 000/μL (17×10^9/L), abdominal tenderness, and a CT grade for mesenteric injury of 4 on a scale delineated by McNutt et al (35), for a maximum possible score of 3 points. In their cohort, 86.7% of patients with a bowel injury prediction score of 2 or 3 had a bowel injury at surgery (35). However, in the results of a subsequent study of a smaller cohort, LeBedis et al (36) found that only 56.3% of patients with surgically proven bowel injury had a bowel injury prediction score of 2 or 3. Further investigation into this model is warranted.

For patients who have questionable findings at the initial CT examination and do not meet the criteria for surgery, admission for observation is recommended. If any signs of peritonitis or clinical deterioration become apparent during observation, surgical intervention is then indicated. For patients with a high risk of bowel or mesenteric injury, repeat CT of the abdomen and pelvis with administration of water-soluble contrast material is recommended, in an effort to maximize the detection of subtle bowel perforation. The exact time to perform repeat CT of the abdomen and pelvis is not firmly established; at our institution, the repeat scan is typically performed 12–24 hours after the initial scan (27). In the findings from one recent study, investigators reported that a repeat CT scan of the abdomen and pelvis, which was performed an average of 20 hours ± 10 after the initial CT scan, altered management in 26 of 100 patients (26%) (37).

In the setting of "shock bowel," the bowel appears thickened secondary to low-volume status, as opposed to direct injury (27). Additional CT findings of hypovolemic shock complex may also be seen, such as a flattened inferior vena cava and adrenal hyperenhancement. After appropriate resuscitation, repeat CT of the abdomen and pelvis may demonstrate improvement in the appearance of the bowel and mesentery, negating the need for surgery in some cases (27).

Multidetector CT Findings

There are several recognized signs of blunt bowel and mesenteric injury at multidetector CT. The direct signs of blunt bowel and mesenteric injury have been studied, and each direct sign has its own accepted sensitivity and specificity. Familiarity with the appearance of the direct and indirect signs of blunt bowel and mesenteric injury, as well as the limitations, is crucial to making a timely diagnosis.

Direct Findings of Blunt Bowel and Mesenteric Injury

Discontinuous Bowel Wall.—Discontinuous bowel wall is the most specific sign of bowel injury. Depiction of a discontinuous bowel wall at multidetector CT in the setting of blunt abdominal trauma is a 100%-specific finding for blunt bowel and mesenteric injury (Figs 1, 2). The radiologist can be sure that there is a bowel injury when this finding is seen. However, this sign is a relatively insensitive finding, with a reported sensitivity of only 5%–10% (38). Although the example images in Figure 1 were acquired after the administration

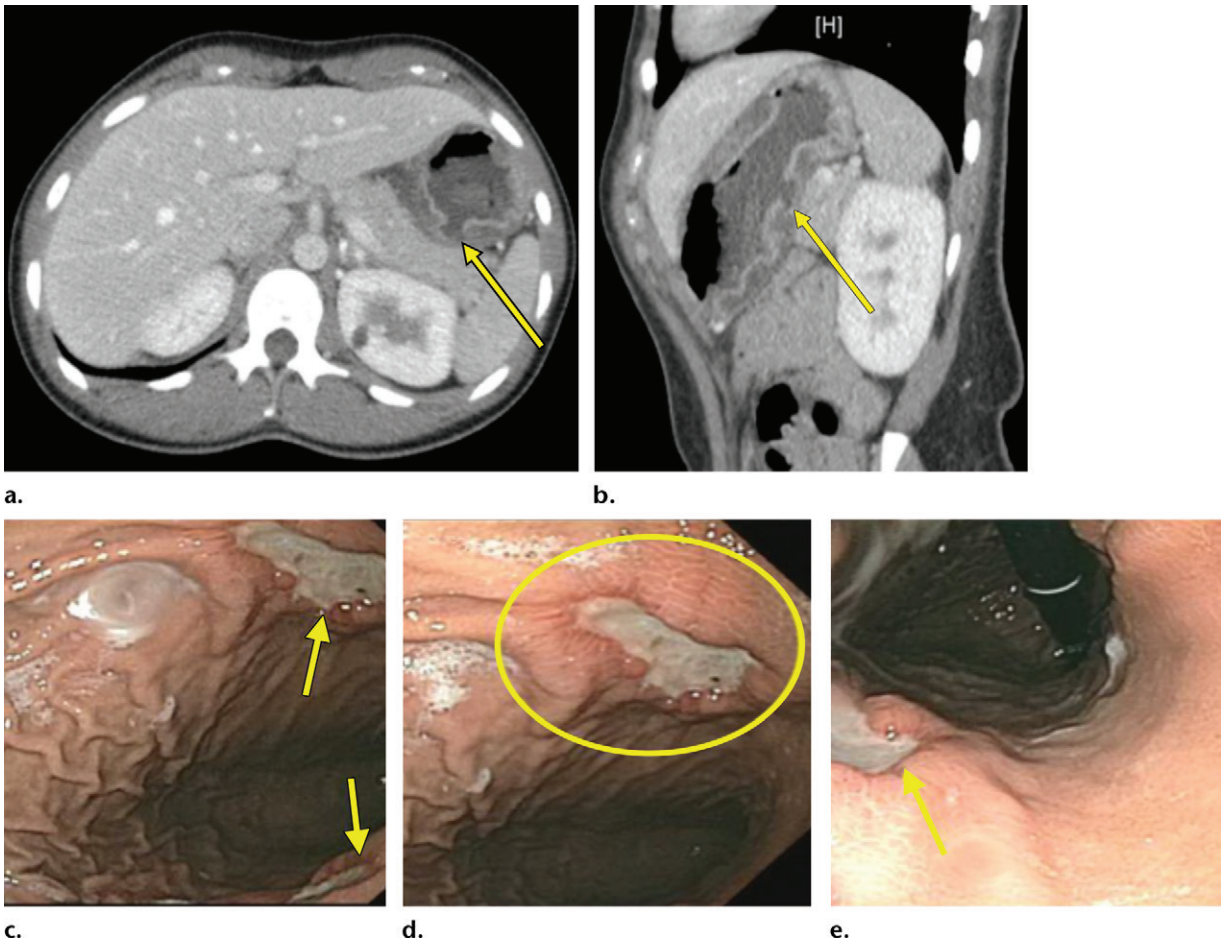


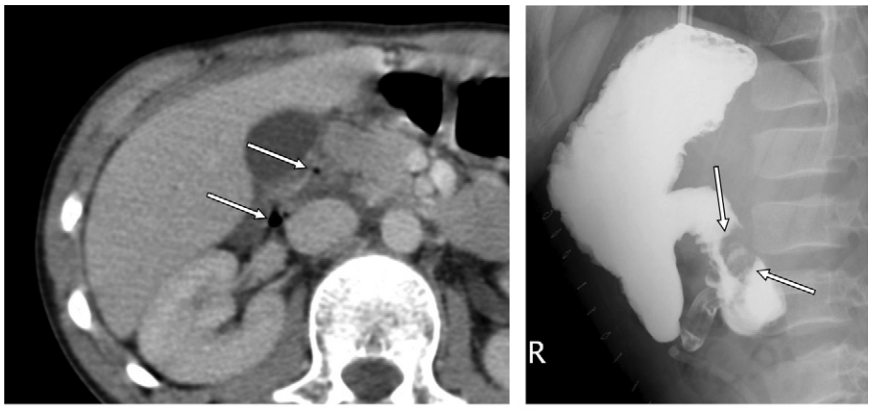
Figure 2. Discontinuous bowel wall in a 25-year-old female go-cart racer who presented with epigastric pain and melena after a crash in which the upper portion of her abdomen impacted the steering wheel. **(a, b)** Axial **(a)** and sagittal **(b)** contrast-enhanced multidetector CT images through the upper part of the abdomen show submucosal edema in the stomach, with a small ulceration posteriorly (arrow). **(c–e)** Upper endoscopic images show posttraumatic opposing ulcers (arrows on **c** and **e**; oval on **d**) on the anterior and posterior walls of the stomach.

of both intravenous and oral contrast materials, the routine administration of oral contrast material is not warranted in patients with blunt abdominal trauma, as discussed previously.

Free Air.—Extraluminal air, or so-called free air, is a fairly reliable sign of bowel injury in patients with blunt abdominal trauma, with a reported specificity of 95%. However, free air is not 100% specific and therefore is not pathognomonic for bowel perforation.

Isolated free intraperitoneal air is not always due to a perforated bowel and may be caused by pneumothorax, chest tube placement, or diaphragmatic injury. However, free air associated with free fluid, the seat-belt sign, or a focal bowel abnormality is highly predictive of bowel injury (39,40). In the results of one study examining false-positive CT findings of free intra-abdominal air, investigators suggested that pneumothorax, chest tube placement, or a diaphragmatic defect may contribute to intraperitoneal air in the absence of bowel perforation (39). Free intraperitoneal air has also been described in the setting of intraperitoneal bladder rupture when a Foley catheter is present (41). However, the presence of free air in combination with other findings, such as the radiologic seat-belt sign (increased attenuation in the subcutaneous fat over the lower abdomen), intraperitoneal free fluid, or a focal bowel abnormality, is highly predictive of bowel injury and warrants exploration (40). Despite the high specificity of free air, it is relatively less sensitive and is seen in only 30%–60% of cases with bowel injury (38).

The location of extraluminal air may be useful in determining the location of the bowel injury. The second to fourth portions of the duodenum, the ascending colon, and the descending colon are retroperitoneal. The first portion of the duodenum, jejunum, ileum, cecum, transverse colon, sigmoid colon, and upper part of the rectum are intraperitoneal. Thus, free air in the retroperitoneum generally indicates injury to one of the



a. b.

Figure 3. Free air in 14-year-old male adolescent who presented with upper abdominal pain after sustaining blunt abdominal trauma from the handlebars of his bicycle. **(a)** Axial contrast-enhanced CT image shows a small amount of extraluminal fluid and free retroperitoneal air (arrows) adjacent to the duodenum, a finding that was suggestive of a duodenal perforation. At laparotomy, this finding was confirmed, and the perforation was repaired. Because of the patient's persistent upper abdominal discomfort, a barium study was performed 6 days later. **(b)** Radiograph from the barium study shows a duodenal filling defect (arrows), which is consistent with a duodenal hematoma.

aforementioned structures. Figure 3 shows free air that is retroperitoneal, secondary to perforation of the second portion of the duodenum.

Indirect Findings of Blunt Bowel and Mesenteric Injury

Abnormal Bowel Wall Enhancement.—Abnormal hypoenhancement of the bowel wall has a sensitivity of 10%–15% for blunt bowel and mesenteric injury but a specificity of 90% (38). The *Janus sign* refers to adjacent enhancing and nonenhancing loops of bowel. The Janus sign has been described as specific for bowel injury (42) (Figs 4, 5). Focal mucosal hyperenhancement of the bowel can be seen in bowel ischemia, particularly after reperfusion from an arterial injury (43).

Focal Bowel Wall Thickening.—Focal thickening of the bowel wall, measuring approximately 3–4 mm, is an important sign of bowel injury in the setting of blunt trauma (Fig 6). Although focal bowel wall thickening is a reliably specific sign, with a reported specificity of 90%, the sign is relatively insensitive, with reported sensitivities ranging from 55% to 75% (10). Because loops of bowel demonstrate a variable appearance with regard to thickness, depending on the degree of distention and the phase of peristalsis, it is possible to dismiss abnormal focally thickened bowel wall as normal.

In contrast, diffuse bowel wall thickening should not be confused with traumatic bowel injury. When diffuse small-bowel wall thickening of more than 10 mm is seen, it should be considered a sign of shock bowel, either with or without associated hypoperfusion complex (44) (Fig 7).

Free Fluid.—The presence of free fluid in the abdomen or pelvis is a concerning finding in the setting of blunt abdominal trauma. The reported sensitivity and specificity of this finding are 90%–100% and 15%–25%, respectively (38). Free intraperitoneal fluid is the most sensitive sign of bowel injury. In particular, the presence of hyperattenuating free fluid must raise suspicion for bowel injury (Figs 8, 9).

Approximately 3% of male patients may have a small amount of low-attenuation simple fluid in the pelvis without an associated intra-abdominal injury (45). However, not all types of free fluid are the same. Two factors to consider when evaluating free intra-abdominal fluid in the setting of trauma are the amount of fluid and its mean attenuation. Female patients, particularly premenopausal female patients, often have a small amount of simple fluid in the pelvis that is considered a physiologic finding. In addition, it has also been shown that approximately 3% of male trauma patients may have a small amount of low-attenuation free intraperitoneal fluid in the absence of any appreciable abdominal injury (45). It is postulated that this free intraperitoneal fluid may be due to aggressive intravenous hydration, but the etiology is not proven. Some trauma centers will admit male patients for observation when isolated free fluid is seen in the setting of trauma, but the management of this group of patients remains controversial.

Mesenteric Infiltration and Extravasation of Contrast Material.—Mesenteric infiltration, or so-called stranding, has a reported sensitivity and specificity for acute mesenteric injury of

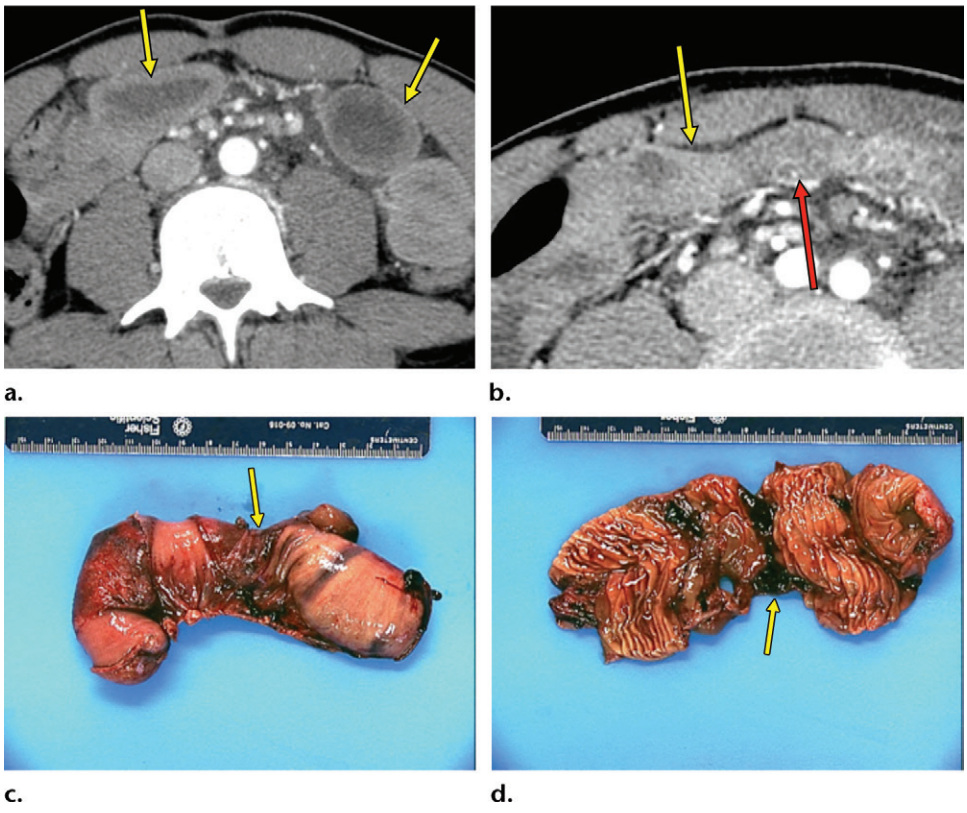


Figure 4. Abnormal bowel wall enhancement in an 18-year-old man who had sustained blunt abdominal trauma. **(a)** Axial multidetector CT image shows small-bowel wall thickening and distention (arrows). **(b)** Axial multidetector CT image of the lower part of the abdomen shows adjacent hyperenhancing (yellow arrow) and hypoenhancing (red arrow) segments of small bowel, the so-called Janus sign. **(c, d)** Photographs of small-bowel specimens obtained at laparotomy show a corresponding small-bowel laceration (arrow) that required resection. (Scales are in centimeters.)

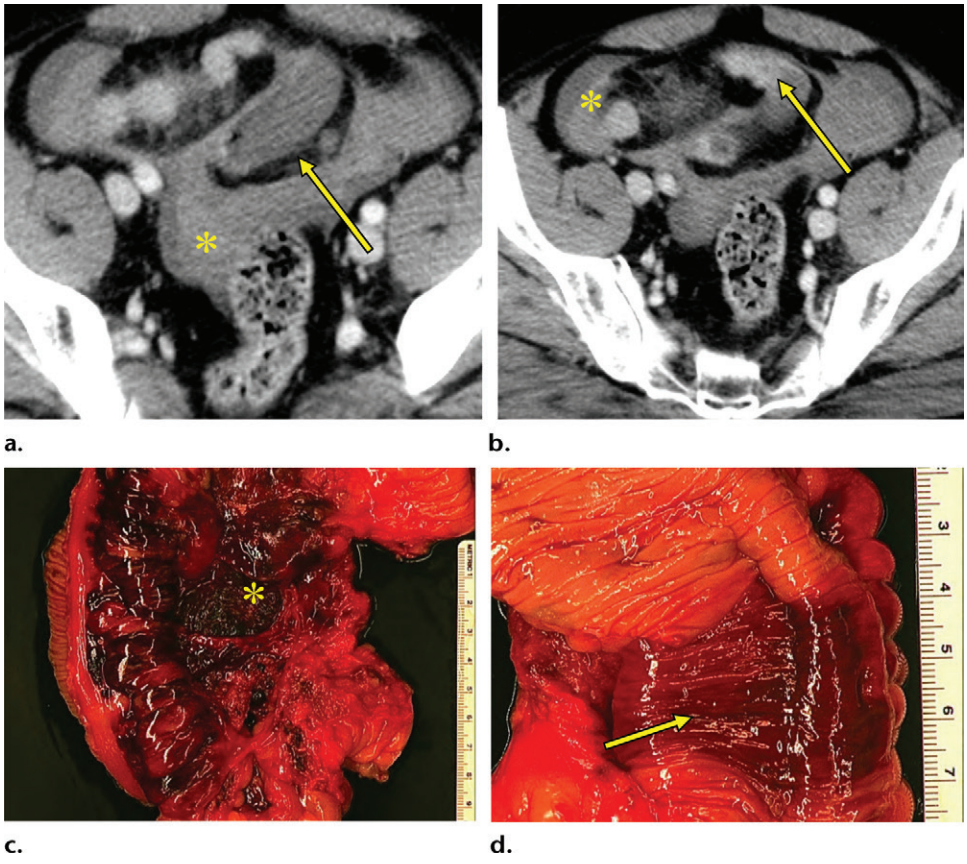


Figure 5. Abnormal bowel enhancement in a 48-year-old male pedestrian who was struck by a motor vehicle. **(a, b)** Axial multidetector CT images (**a** obtained slightly lower than **b**) show focal hypoenhancement of the terminal part of the ileum (arrow on **a**) with an adjacent enhancing loop of bowel (arrow on **b**), the so-called Janus sign. Hyperattenuating free fluid is also depicted in the pelvis (*). **(c, d)** Photographs of surgical specimens show an ileal mesenteric tear with mesenteric hemorrhage (* on **c**), in association with ileal necrosis (arrow on **d**). (Scales are in centimeters.)

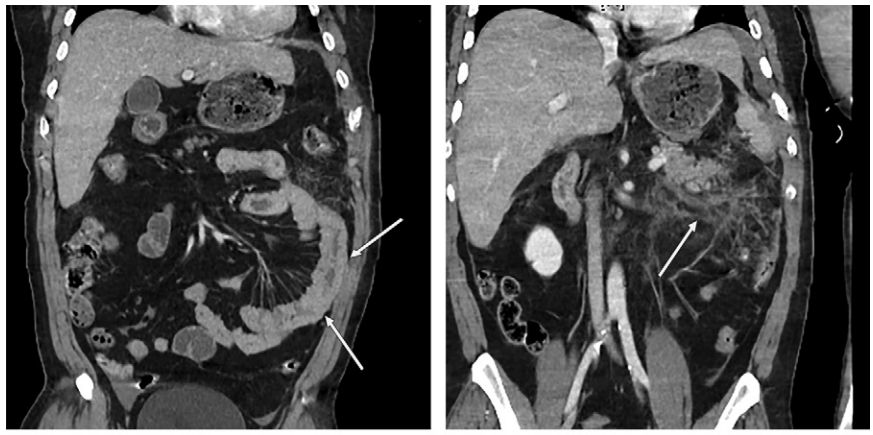


Figure 6. Focal bowel wall thickening in a 51-year-old male pedestrian who was struck by a motor vehicle. Coronal multidetector CT images (**a** obtained more anterior than **b**) show a short segment of focal bowel wall thickening (arrows on **a**) and mesenteric stranding (arrow on **b**). Hepatic and splenic lacerations were also seen (not shown). At surgery, tears of the small-bowel mesentery were encountered, as well as tears of the transverse and descending colon.

Figure 7. Diffuse small-bowel wall thickening in a 19-year-old man. Axial contrast-enhanced CT image shows diffuse small-bowel wall thickening. Diffuse bowel wall thickening and mucosal hyperenhancement in the setting of trauma is usually the result of hypoperfusion, the so-called shock bowel, rather than the result of blunt traumatic injury.

70%–77% and 40%–90%, respectively. Mesenteric stranding is characterized by a hazy appearance and increased attenuation in the mesentery. The finding is suggestive of mesenteric hematoma or contusion and may be seen either with or without an associated bowel injury (7) (Figs 10–12). In contrast to simple mesenteric infiltration, extravasation of contrast material in the mesentery is much more specific and generally requires surgical intervention (7).

Associated Findings in Patients with Blunt Bowel and Mesenteric Injury

Chance Fracture.—Chance (46) first described this fracture in 1948, stating that "when flexion of the spine exceeds normal limits something has to give way." This flexion injury involves distraction of the posterior elements and is associated with a substantial rate of intra-abdominal injury.

In the results of one retrospective series, Bernstein et al (47) reported that intra-abdominal injuries were seen in approximately 40% of 53 patients with Chance-type vertebral fractures after blunt abdominal trauma. Bowel injury was particularly likely when the fracture pattern had a burst component (47). Chance-type fractures may be seen in isolation or in combination with other signs of bowel injury (Fig 13).

Multiple Abdominal Visceral Injuries.—The incidence of blunt bowel and mesenteric injury increases substantially as the number of abdominal solid-organ injuries rises. When three abdominal solid organs are injured, the risk for bowel injury is 34% (48). The presence of multiple abdominal viscus injuries is associated with hollow-organ injury (Fig 14). It has been shown that the risk of an associated hollow-organ injury increases with an increasing number of injured solid organs. For example, in one study, investigators found that the rate of hollow-organ injury was 7.3% when one solid organ was injured, 15.4% when two solid organs were injured, and 34.4% when three solid organs were injured (48). The same investigators reported a significant increase in the incidence of hollow-organ injury, from 7.8% to 22.8% ($P < .001$), when the sum of the abbreviated injury scores (8) for solid organs was greater than or equal to 6 (48).

Pancreatic Injuries.—Pancreatic injuries will have associated duodenal injuries in approximately 20% of cases (49). Pancreatic injuries are relatively uncommon, reportedly found in 2%–12% of patients with blunt abdominal trauma (50). Injury to the pancreas typically results from a direct impact to the upper part of the abdomen. The neck and body of the pancreas are most commonly injured by compression against

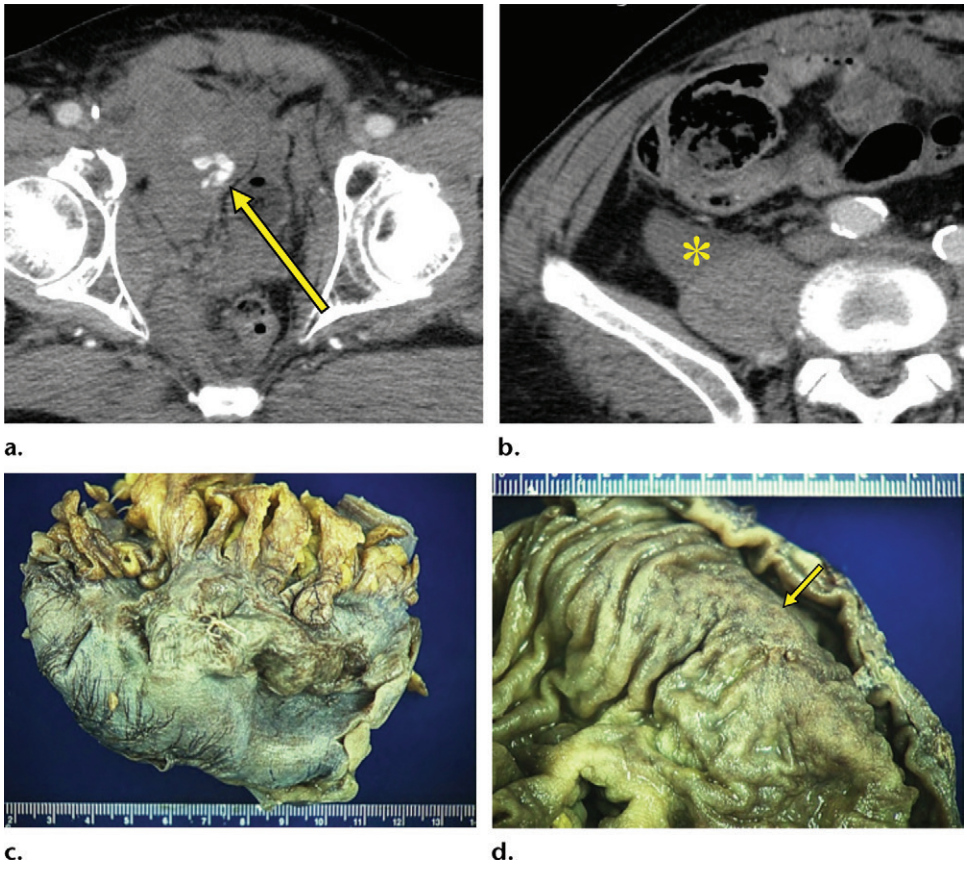


Figure 8. Free fluid in a 77-year-old male pedestrian struck by a motor vehicle. Multidetector CT demonstrated pelvic fractures (not shown). **(a)** Axial contrast-enhanced CT image shows a large pelvic hematoma displacing the urinary bladder and active extravasation of contrast material (arrow). **(b)** Axial contrast-enhanced CT image shows that the cecum and ileum appear relatively normal, although there was a moderate amount of hyperattenuating fluid in the right paracolic gutter (*). **(c, d)** Photographs of surgical specimens show the resected cecum. Note the dusky ischemic appearance of the cecal mucosa (arrow on **d**). At laparotomy, ischemia of the cecum and ileum was seen, a finding that required ileocecectomy. (Scales are in centimeters.)

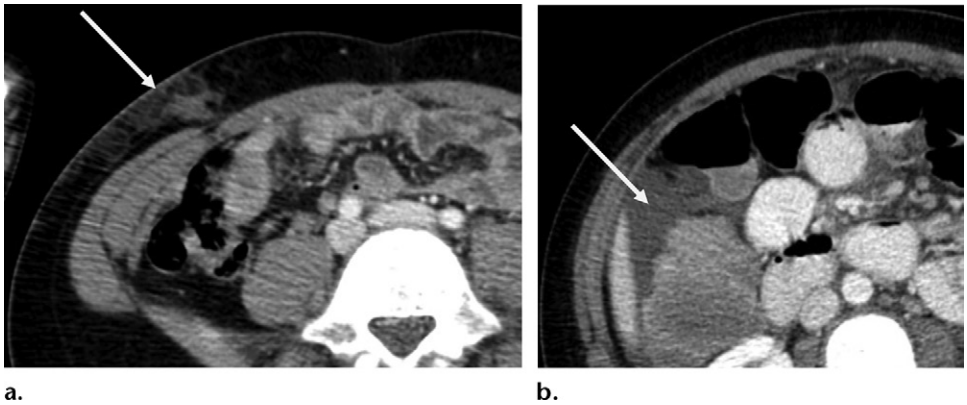


Figure 9. Free fluid in an 8-year-old boy who presented with abdominal pain after a motor vehicle collision. **(a)** Initial axial multidetector CT image obtained at the time of the motor vehicle collision shows a contusion (arrow) in the subcutaneous tissues of the anterior abdominal wall (the so-called seat-belt sign) and a trace of hyperattenuating intraperitoneal fluid in the pelvis. Because of ongoing abdominal symptoms, the patient underwent a repeat CT examination 3 days later with oral contrast material administration. **(b)** Repeat axial contrast-enhanced CT image shows an increased amount of free fluid (arrow). Although extraluminal oral contrast material was not identified, the presence of an increasing amount of hyperattenuating free fluid raised suspicion for bowel injury. At laparotomy, a jejunal perforation was discovered and primarily repaired, without the need for resection.

the vertebral column. When a deep pancreatic laceration is depicted, defined as a linear area of hypoattenuation that is greater than 50% of the gland thickness, a main pancreatic duct injury should be presumed, and further evaluation with magnetic resonance cholangiopancreatography is warranted. Duodenal injuries are associated with pancreatic lacerations in the setting of blunt trauma. In addition, pancreatic injuries are associated with duodenal injuries.

Distinguishing among duodenal contusion, duodenal hematoma, and duodenal perforation is essential, because management varies depending on the diagnosis. Duodenal perforation

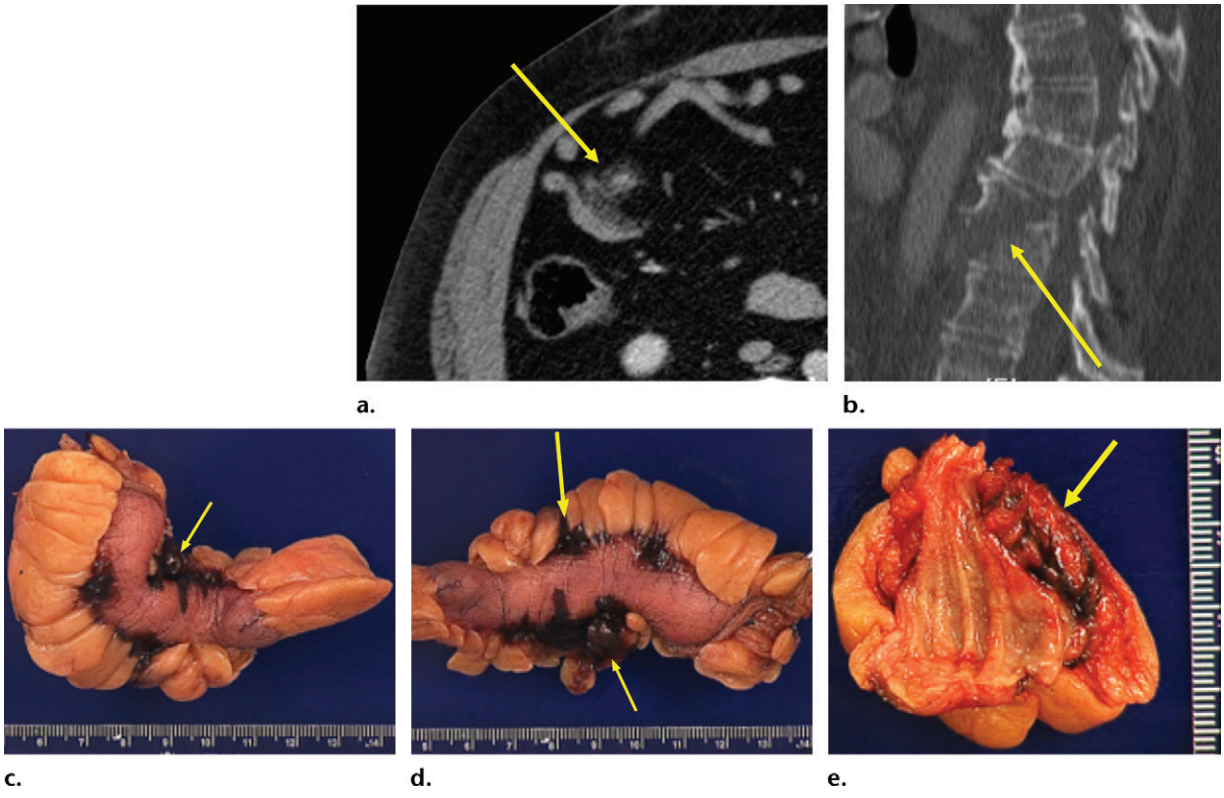


Figure 10. Mesenteric stranding in a 68-year-old man who was transferred from another hospital after a motor vehicle collision. **(a)** Axial contrast-enhanced CT image shows mesenteric stranding in the right lower quadrant, with a small blush of contrast material (arrow), but no apparent bowel wall thickening. **(b)** Sagittal reformatted CT image shows an unstable fracture (arrow) in the lower part of the thoracic spine. **(c–e)** Photographs of surgical specimens show areas of ischemic small bowel (arrows) with adjacent hemorrhagic fat, findings that required resection. (Scales are in centimeters.)

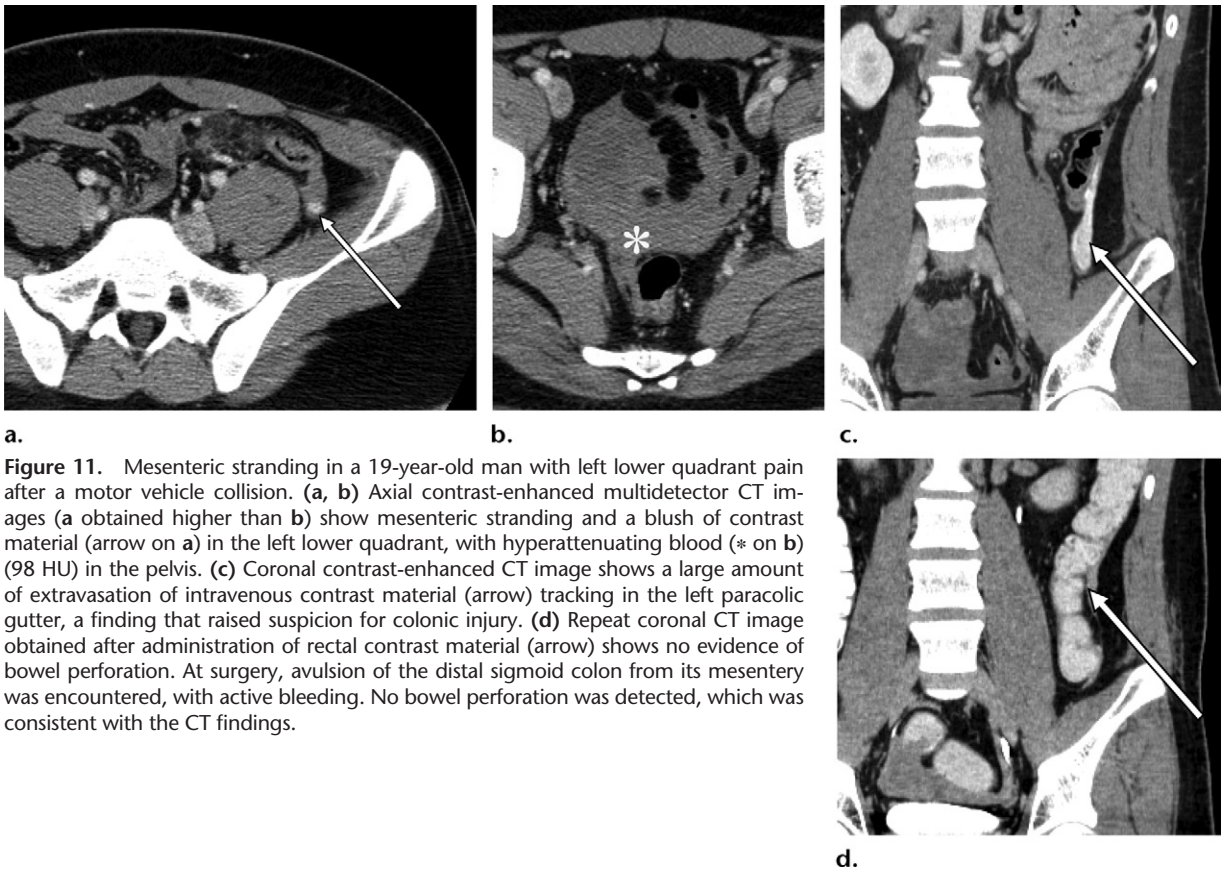


Figure 11. Mesenteric stranding in a 19-year-old man with left lower quadrant pain after a motor vehicle collision. **(a, b)** Axial contrast-enhanced multidetector CT images (**a** obtained higher than **b**) show mesenteric stranding and a blush of contrast material (arrow on **a**) in the left lower quadrant, with hyperattenuating blood (∗ on **b**) (98 HU) in the pelvis. **(c)** Coronal contrast-enhanced CT image shows a large amount of extravasation of intravenous contrast material (arrow) tracking in the left paracolic gutter, a finding that raised suspicion for colonic injury. **(d)** Repeat coronal CT image obtained after administration of rectal contrast material (arrow) shows no evidence of bowel perforation. At surgery, avulsion of the distal sigmoid colon from its mesentery was encountered, with active bleeding. No bowel perforation was detected, which was consistent with the CT findings.

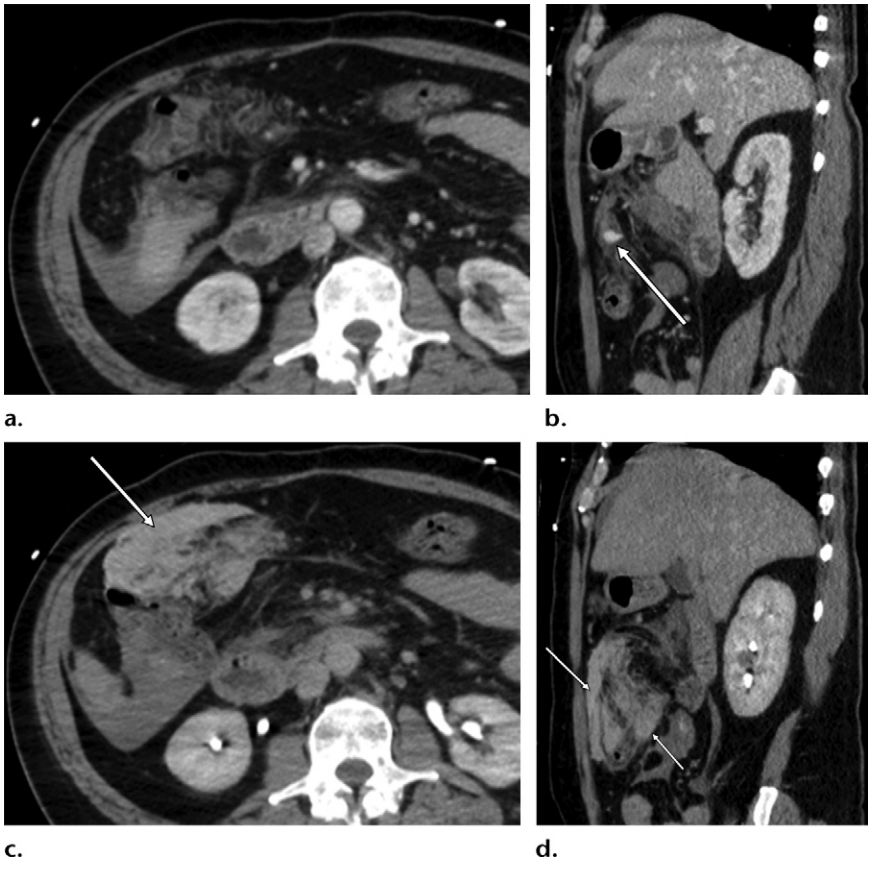


Figure 12. Mesenteric hematoma in a 52-year-old man with abdominal pain and hypotension after an assault. **(a, b)** Axial **(a)** and sagittal **(b)** contrast-enhanced CT images obtained in the portal venous phase show hyperattenuating ascites and mesenteric hematoma in the upper part of the abdomen, with a small blush of active extravasation of contrast material (arrow on **b**). **(c, d)** Axial **(c)** and sagittal **(d)** contrast-enhanced CT images obtained in the delayed phase at 5 minutes show a massive extravasation of contrast material (arrows). At emergent laparotomy, a large expanding hematoma was encountered in the transverse mesocolon, a finding that necessitated transverse colectomy. The amount of contrast material extravasation on delayed images can provide useful information about the severity of active hemorrhage. In this case, the large amount of contrast material extravasation is the most important finding, because it indicates brisk loss of blood.

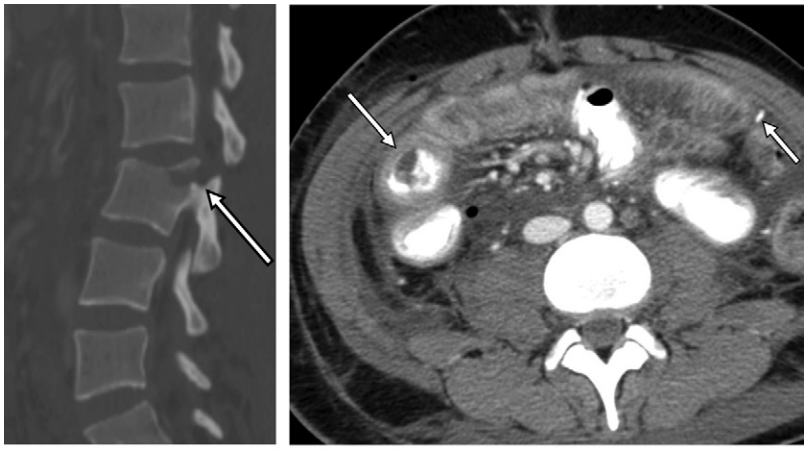


Figure 13. Chance-type fracture in a 25-year-old woman with abdominal and back pain after a motor vehicle collision. **(a)** Sagittal multidetector CT image shows a hyperflexion injury of the lumbar spine, with an L2 vertebra fracture and distraction of the posterior elements (arrow), the so-called Chance fracture. **(b)** Axial CT image of the abdomen shows bowel wall edema and mucosal hyperenhancement (arrows). At laparotomy, devascularized ischemic bowel was encountered, a finding that required right hemicolectomy and partial small-bowel resection.

may demonstrate extraluminal enteric contrast material, free retroperitoneal air, or a discontinuous duodenal wall; retroperitoneal fluid may be seen in both duodenal contusion and duodenal perforation (49). Evidence exists to suggest that extraluminal retroperitoneal air is more sensitive than retroperitoneal fluid in the identification of cases of duodenal perforation (51,52).

Conclusion

Blunt bowel and mesenteric injury is relatively uncommon in the setting of blunt abdominal trauma. However, a timely diagnosis is paramount to the proper triage and management of trauma patients. Even relatively short delays in diagnosis can have substantial negative consequences for patients, including prolonged hospital stays, increased rates of sepsis, and increased mortality. Familiarity with the direct and indirect signs of blunt bowel and mesenteric injury, as well as the common pitfalls, is essential. Comparing the findings on multidetector CT images with the surgical and pathologic findings may help develop an understanding of

Figure 14. Multiple abdominal visceral injuries in a 29-year-old man who presented with abdominal pain after a rollover motor vehicle collision. Multidetector CT images demonstrated multiple solid-organ injuries, including a liver laceration extending to the porta hepatis, a right adrenal hemorrhage, and a splenic laceration (not shown). No abnormal bowel findings were identified at imaging. However, an intraoperative photograph shows a serosal contusion of the hepatic flexure (arrow).

the scope of injuries in patients with blunt bowel and mesenteric injury, thus aiding the diagnostic accuracy and confidence of the radiologist.

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