CT of Blunt Trauma Bowel and Mesenteric Injury: Typical Findings and Pitfalls in Diagnosis[1]

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Detection of bowel and mesenteric injury can be challenging in patients after blunt abdominal trauma. Early diagnosis and treatment are critical to decrease patient morbidity and mortality. Computed tomography (CT) has become the primary modality for the imaging of these patients. Signs of bowel perforation such as free air and contrast material are virtually pathognomonic. Bowel-wall thickening, free fluid, and mesenteric infiltration may be seen with this type of injury and partial thickness injuries. The authors present and discuss the range of CT findings seen with bowel and mesenteric injuries. Examples of observation and interpretation errors are also provided to highlight pitfalls encountered in the evaluation of abdominopelvic CT scans in patients after blunt trauma.

Index terms: Gastrointestinal tract, CT, 74.1211, 75.1211 • Gastrointestinal tract, hemorrhage, 74.41, 74.43, 75.41, 75.43 • Gastrointestinal tract, perforation, 74.41, 74.43, 75.41, 75.43 • Intestines, hemorrhage, 74.41, 74.43, 75.41, 75.43 • Intestines, injuries, 74.41, 74.43, 75.41, 75.43 • Intestines, perforation, 74.41, 74.43, 75.41, 75.43 • Trauma

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See the commentary by Mirvis following this article.

Introduction

Hemoperitoneum detected with diagnostic peritoneal lavage or ultrasonography is no longer an unequivocal indication for exploratory laparotomy in a stable patient. More emphasis is now placed on nonsurgical management of liver and spleen injuries (1,2). The concurrent presence of significant bowel or mesenteric injury, however, would make conservative treatment inappropriate and necessitate exploratory laparotomy. Therefore, greater sensitivity and specificity of imaging studies are demanded for these types of injury.

Almost 2 decades ago, the first articles describing the use of computed tomography (CT) for detection of intestinal injuries due to blunt trauma appeared in the English language literature (3,4). Despite publication of more comprehensive observations from the radiology community (5–8), findings in the surgical literature described CT as unreliable (9,10). However, CT continued to evolve and can now help identify most significant traumatic bowel and mesenteric injuries in both children and adults (5,11). A survey of the members of the American Association for the Surgery of Trauma (12) showed 77% now use CT scanning most or all of the time for diagnosis of blunt injury of the small bowel. The current surgery literature even suggests that a negative CT scan can be used as a screening tool to help identify patients who may be discharged without further evaluation (13). Because so much emphasis is now placed on CT, this article highlights the typical CT findings associated with bowel and mesenteric injury due to blunt trauma. The CT signs presented in this article include bowel discontinuity, extraluminal oral contrast material, extraluminal air, intramural air, bowel-wall thickening, bowel-wall enhancement, mesenteric infiltration, as well as intraperitoneal and retroperitoneal fluids. In addition, we present some pitfalls that may lead to misinterpretation.

Patients and CT Studies

Interrogation of the trauma registry at our level I trauma center and the examination report database of the radiology department for January 1993 through December 1999 identified 35 patients who had both laparotomy-proved bowel or mesenteric injury and a preoperative contrast material–enhanced abdominopelvic CT scan. In all cases, various conventional nonspiral CT scanners (GE Medical Systems, Milwaukee, Wis) were used with a bolus of ionic or nonionic contrast material administered intravenously at rates of 1–3 mL/sec. All but four patients received enteric contrast material administered orally or through a nasogastric tube.

All original studies were retrieved and retrospectively reviewed for evidence of bowel or mesenteric injury on the basis of signs previously described in the literature (5,7,11). Signs identified during retrospective CT review were correlated with surgical findings extracted from the surgical notes.

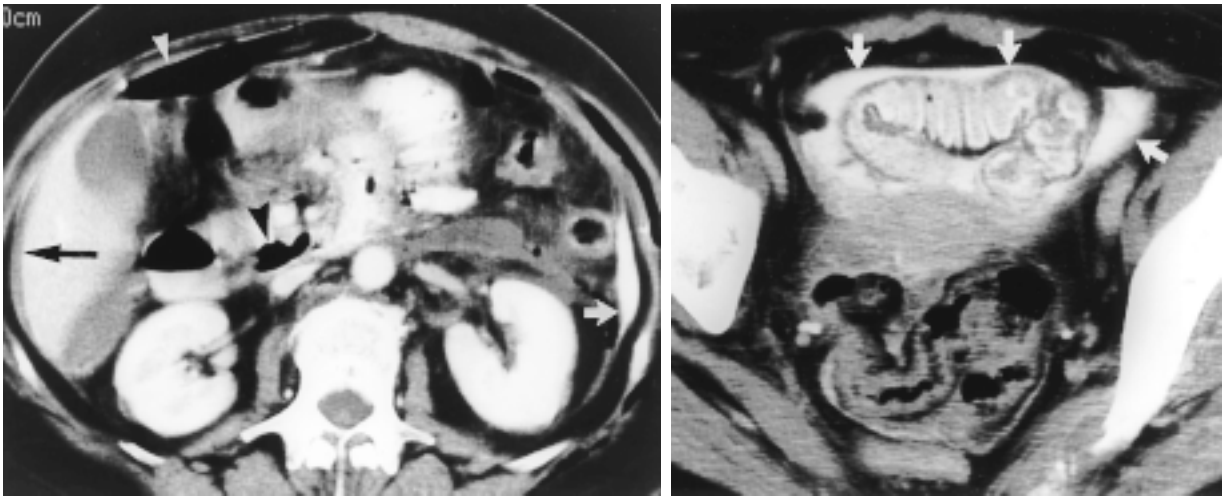
CT Findings of Bowel or Mesenteric Injury

Bowel Discontinuity

Discontinuity of bowel is the primary finding of bowel injury. This findings was not present in any of our cases, and examples are uncommon in the literature (14). Because direct visualization is unusual, one must generally rely on secondary findings.

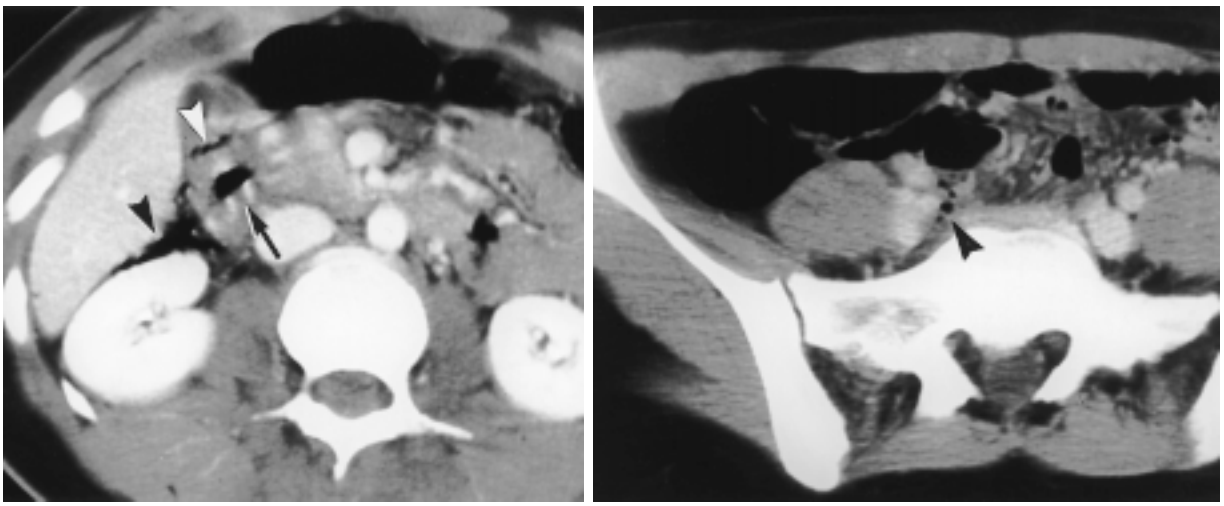
Extraluminal Oral Contrast Material

Free intraperitoneal oral contrast material is 100% specific for bowel perforation (Fig 1) if concentrated intravenous contrast material from genitourinary tract perforation is not a confounding factor. The sensitivity of this CT finding is 12% or less in the literature (15,16).



a. b.

Figure 1. Duodenal and jejunal perforations in a 65-year-old woman. **(a)** Abdominal CT scan reveals free fluid (black arrow), free intraperitoneal air (white arrowhead), retroperitoneal air (black arrowhead), and intraperitoneal contrast material (white arrow). **(b)** On a CT scan obtained at a lower level, a large quantity of free contrast material outlines a pelvic small-bowel loop (white arrows).



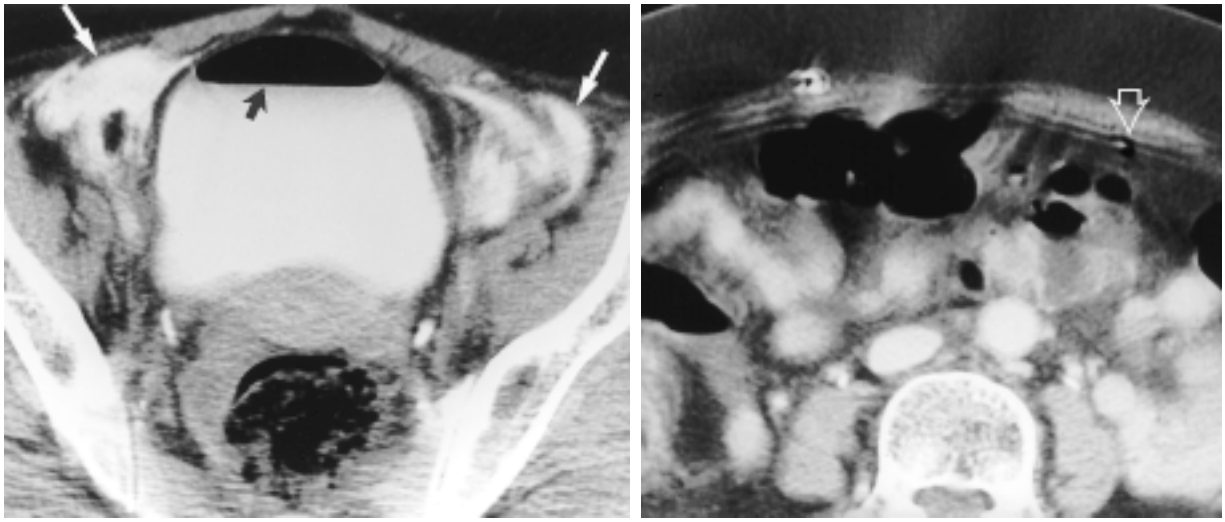
a. b.

Figure 2. Perforation of the duodenal "C" loop in a 17-year-old girl. **(a)** Abdominal CT scan shows a thick-walled duodenum (arrow), outlined by extraluminal retroperitoneal air (arrowheads). **(b)** CT scan of the pelvis reveals foci of retroperitoneal air that have escaped from the duodenal perforation (arrowhead).

Extraluminal Air

The finding of pneumoperitoneum (Fig 1) has a sensitivity of 44%–55% (7,14,15). Pneumoretroperitoneum in the setting of duodenal injury seems to be a more sensitive finding (Fig 2) (3,6).

Extraluminal intra- or retroperitoneal air is not diagnostic of bowel perforation. Although bowel perforation is a major source of this finding, barotrauma and mechanical ventilation can result in air below the diaphragm (17,18). Air



a. **b.**

Figure 3. Extraperitoneal bladder rupture and normal bowel loops in a 77-year-old woman. **(a)** CT cystogram obtained after retrograde filling of the bladder shows an intravesicle air-contrast level (black arrow) and contrast material in the perivesicle extraperitoneal space (white arrows). **(b)** On a CT image obtained at a higher level, abdominal wall motion artifact blurs the outline of a small focus of air in the preperitoneal space (arrow). The air was introduced during retrograde bladder filling and mimics free intraperitoneal air.

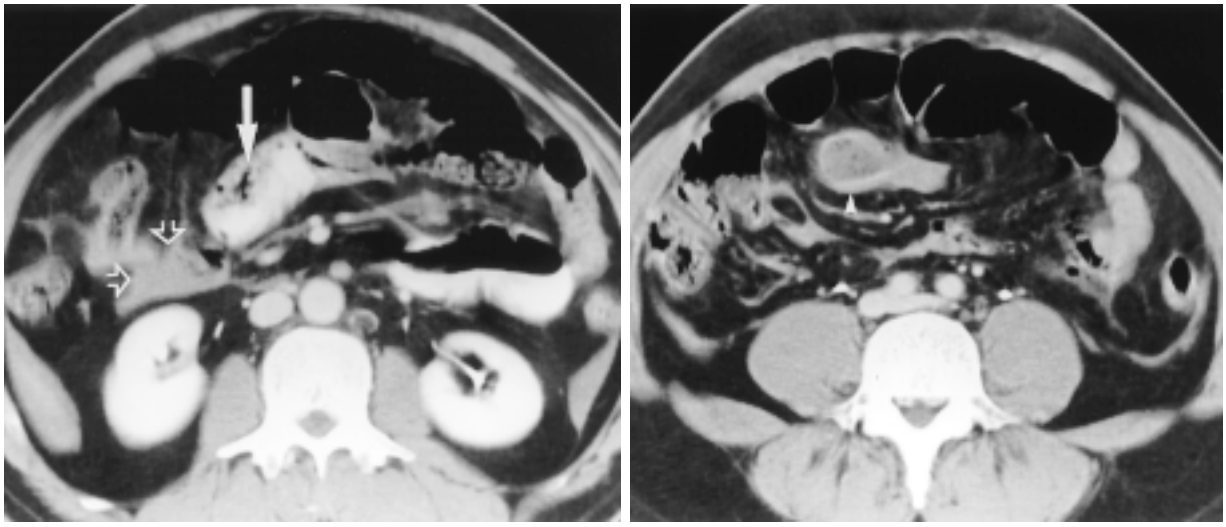


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Figure 4. Proximal ileum perforation and mesenteric hematoma in a 41-year-old man. **(a)** Abdominal CT scan demonstrates intramural air in the ileum (solid arrow) and adjacent interloop free fluid (open arrows). **(b)** CT scan obtained at a lower level shows mucosal enhancement (arrowhead) of a more distal ileal segment.

introduced during CT cystography may escape through a bladder laceration (Fig 3). Whenever free air is detected, other secondary indications of bowel injury should be sought to determine its significance.

Intramural Air

Major bowel injuries (those requiring laparotomy, such as perforations) and minor bowel injuries (which can be treated conservatively, such as serosal abrasions) have findings of bowel-wall thickening and free fluid in common. CT does

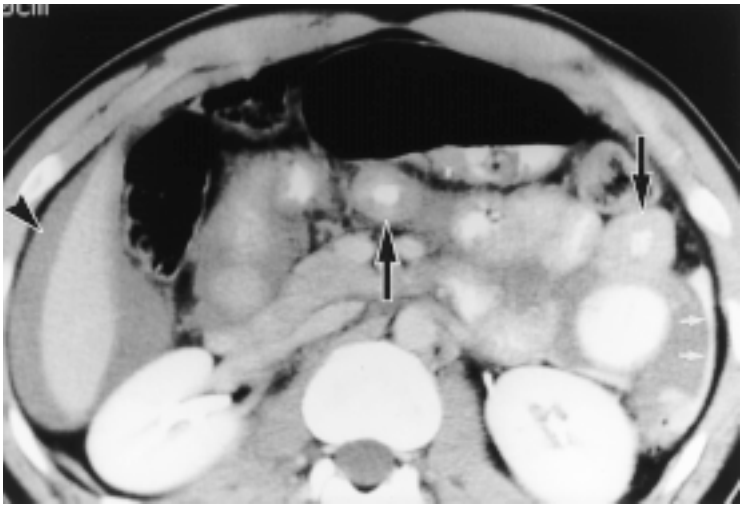


Figure 5. A 10-cm-long jejunal laceration and mesenteric avulsion of the descending colon in a 35-year-old man. CT scan demonstrates thick-walled jejunal loops (black arrows), hemoperitoneum (arrowhead), and free intraperitoneal contrast material (white arrows).

not appear to be able to readily help distinguish the two in all instances (14). Along with extraluminal air, the presence of intramural air will highlight a probable full-thickness rather than partial-thickness injury (Fig 4).

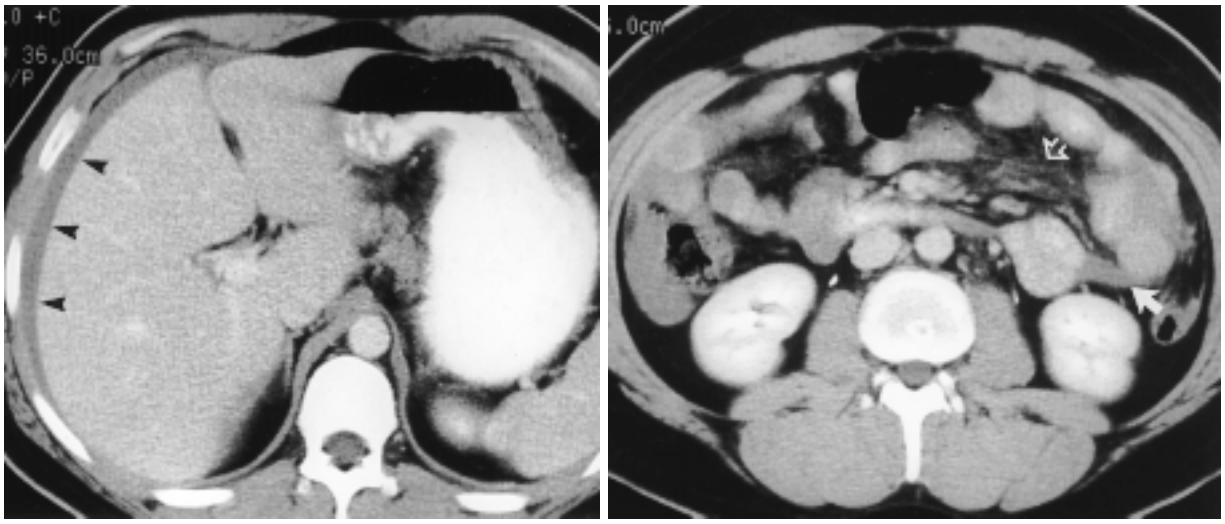
Bowel-Wall Thickening

Bowel-wall thickening, seen in 75% of transmural injuries, is more sensitive for bowel-wall injury than is extravasation of oral contrast material or pneumoperitoneum (Fig 5) (15). Isolated mesenteric lacerations may also demonstrate this sign, probably as a result of interruption of the arterial supply or venous drainage. Unfortunately, this finding can often be very subjective. Some authors say wall thickness greater than 3 or 4 mm is abnormal in an attempt to better quantify this abnormality (5,7,14,19). Only a few articles in the trauma literature take into account the degree of luminal distention (6,20). We use a combination of observations by Kunin et al (6) and Strouse et al (11): Disproportionate thickening compared with normal segments or bowel-wall thickness greater than 3 mm with adequate bowel distention is abnormal. In an attempt to reduce the number of false-positive findings, we also require circumferential involvement. Normal bowel with small amounts of air distention can have wall thickening in a dependent position but a normal thin wall outlined by air on the inner mucosal surface in the nondependent position.

Bowel-Wall Enhancement

Taylor et al (21) initially described bowel-wall enhancement without perforation as part of the hypoperfusion complex (shock bowel) in children. Results of subsequent studies have shown that bowel-wall enhancement can also occur in a high percentage of children with perforation but no evidence of the hypoperfusion complex (22–24). An adult form of the complex with a lower frequency of bowel-wall enhancement has been reported (20). These patients also had diffuse thickening of the wall of the small bowel and fluid distention, but unlike the series of children, some had bowel perforation along with signs of hypoperfusion. The proposed cause of enhancement of reduced perfusion and interstitial leak of contrast material (20) fits into the categories of either local vascular damage related to bowel or mesenteric injury or the more systemic hypoperfusion complex.

The definition of bowel-wall enhancement is not uniform. Empiric assessment (20,24), enhancement greater than that of the psoas muscle (23), or enhancement equal to that of adjacent blood vessels (22) have all been used. None of our cases showed full-thickness wall enhancement equal to that of adjacent vessels, but three cases demonstrated mucosal enhancement (Fig 4b). These cases involved limited segments, and



a. **b.**

Figure 6. Midjejunal partial thickness tear but normal liver and spleen in a 20-year-old man. **(a)** Abdominal CT scan shows hemoperitoneum surrounding the intact liver capsule (arrowheads). **(b)** CT scan obtained at a lower level reveals interloop fluid (solid arrow) and mesenteric stranding (open arrow) in the absence of bowel-wall thickening, findings that are more suggestive of mesenteric injury than of parenchymal organ damage.

one was in the region of perforation and the other two were not. It is unclear how the normal high levels of contrast enhancement achieved with spiral CT scanners will affect the specificity of this sign.

Mesenteric Infiltration

Mesenteric infiltration or "stranding" can be associated with mesenteric injury with or without bowel perforation (Fig 6), but bowel-wall thickening associated with stranding is highly suggestive of significant bowel injury (11,19). Sensitivities and specificities of 69%–77% and 44%–100%, respectively, have been reported for this sign (14, 25). Mesenteric findings are more common when bowel injury is along the mesenteric border (25). A localized hematoma within the mesentery in the absence of a bowel abnormality points to an isolated laceration of a mesenteric vessel (Figs 7, 8) (26).

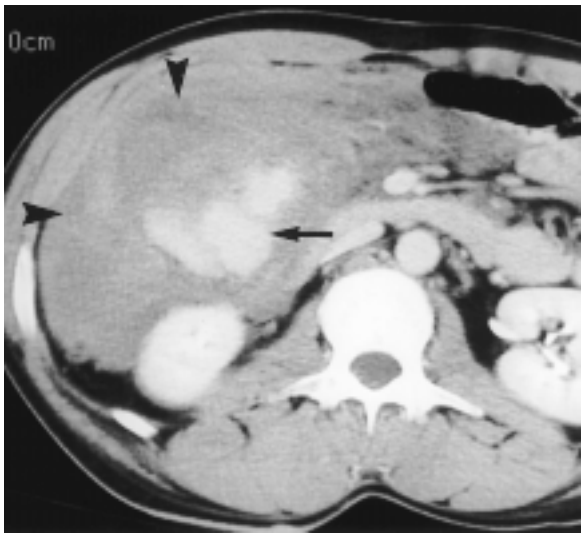
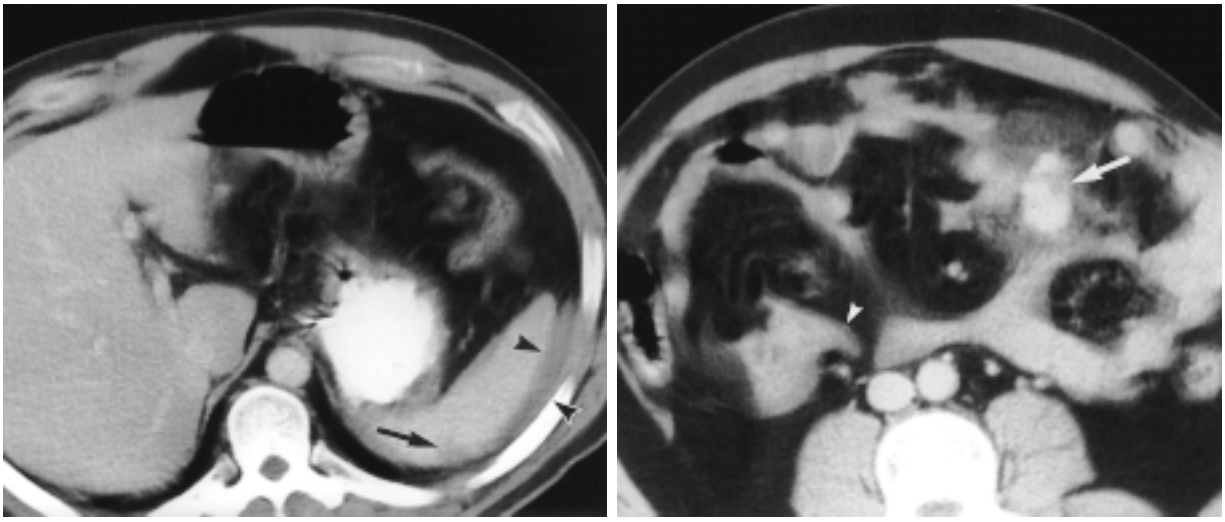


Figure 7. Middle colic artery laceration in a 38-year-old man. CT scan shows a lobulated hyperattenuating area (arrow) that represents extravasation of contrast material within an otherwise nonopacified hematoma (arrowheads).

Intraperitoneal and Retroperitoneal Fluids

Hematomas can occur in the peritoneal cavity, retroperitoneum, or both. Retroperitoneal hematoma along with wall thickening helps identification of duodenal trauma and is frequently present with this type of injury (Fig 9) (6). Hemoperitoneum is a common finding in patients with intraperitoneal bowel or mesenteric laceration (88%–100% of patients) (7,15). Periduodenal hematoma is a fairly specific sign of duodenal injury because retroperitoneal blood tends to localize at the site of injury. This is in contrast with intraperitoneal



a. **b.**

Figure 8. Splenic and mesenteric lacerations in a 41-year-old man. **(a)** Abdominal CT scan reveals a splenic laceration (arrow), which contributed to hemoperitoneum (arrowheads). **(b)** CT scan obtained at a lower level shows a focus of contrast material extravasation (arrow) and adjacent stranding, findings that help identify the mesenteric laceration. (Note: A low rate of intravenous administration of contrast material results in faint attenuation of the contrast material extravasation.) Adjacent interloop fluid (arrowhead) is present.

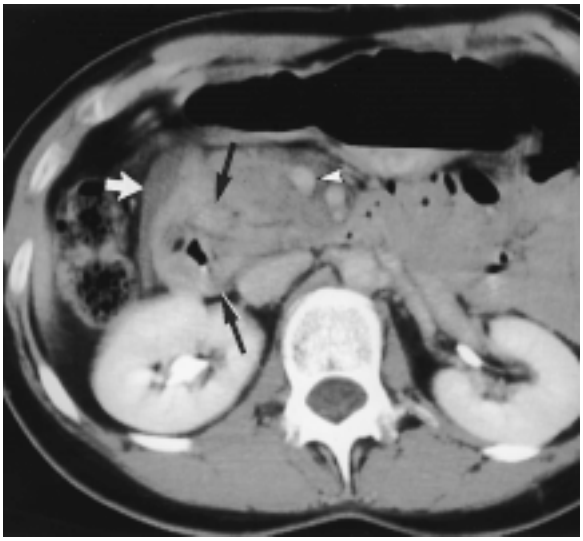
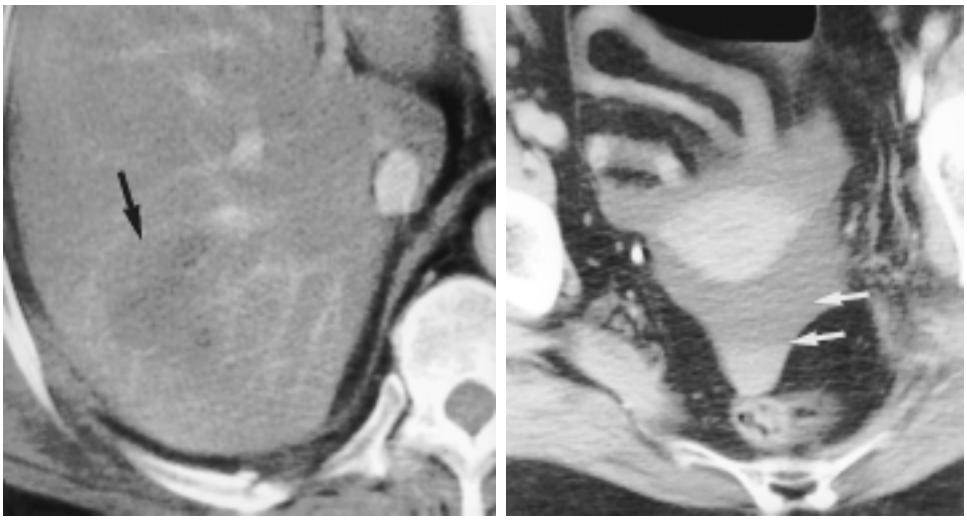


Figure 9. Duodenal and pancreatic contusions with adjacent hematoma in a 36-year-old woman. CT scan shows a thick-walled duodenum (black arrows) with surrounding blood (white arrow) and additional blood surrounding mesenteric vessels (arrowhead). No free air is seen. The pancreas appeared normal on other CT images (not shown).

blood for which the absence of restriction allows blood from solid organ injury to flow freely where it may be associated with normal bowel loops. It follows that hemoperitoneum in the absence of solid organ injury would imply bowel or mesenteric laceration as the source of bleeding (Fig 6). In this setting, free fluid on more than three contiguous 10-mm-thick sections suggests the presence of a significant bowel or mesenteric injury (27).

There is a 5% frequency of major bowel injury with hepatic laceration and 4% with splenic trauma (28). In the absence of bowel-wall thickening, mesenteric stranding, or free air, a simultaneous injury to mesentery or bowel might not be suspected if free fluid is instead linked to solid organ damage. However, fluid location may be helpful. Interloop fluid specifies fluid between the folds of mesentery and bowel (Figs 4a, 6b). These usually polygonal collections are uncommonly associated with solid organ injury (8,15) and more likely to be related to bowel or mesenteric injury.

An intraparenchymal contusion is also a solid organ injury, but it does not extend to cause capsular disruption and would not be expected to result in hemoperitoneum. Bowel or mesenteric injury should be suspected in this instance (Fig 10).



a. **b.**

Figure 10. Multiple mesenteric tears in a 75-year-old woman. Abdominal CT scan **(a)** shows a liver laceration (black arrow). This injury was erroneously thought to be the cause of layering hemoperitoneum outlining the uterus (white arrows), seen on a CT scan of the pelvis **(b)**. Subsequent laparotomy demonstrated an intact liver capsule with mesenteric lacerations as the bleeding source. CT scans obtained through the mesentery were normal (not shown).

Fluid in the intra- or extraperitoneal compartments may not be from hemorrhage but rather may be due to leakage of bowel contents, urine, bile, or pancreatic juice, or the introduction of diagnostic peritoneal lavage fluid. Of these fluids, opacified intraperitoneal urine would most completely mask the presence of intraperitoneal blood or bowel contents (Fig 11). Hemorrhage from damage to other organs (7) in the same anatomic space can also be misleading (Figs 12, 13).

Errors in Diagnosis

Although some signs are usually present, their absence or relation to organs other than the bowel and mesentery results in a misleading CT scan and unavoidable misdiagnosis. When clearly defined signs are not present, a combination of CT and clinical findings helps lead to appropriate patient care (29).

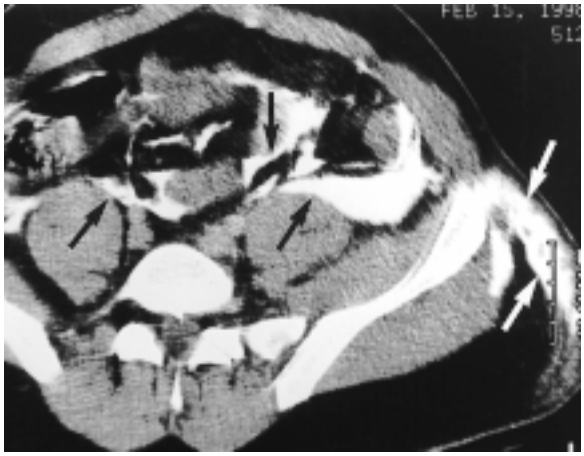
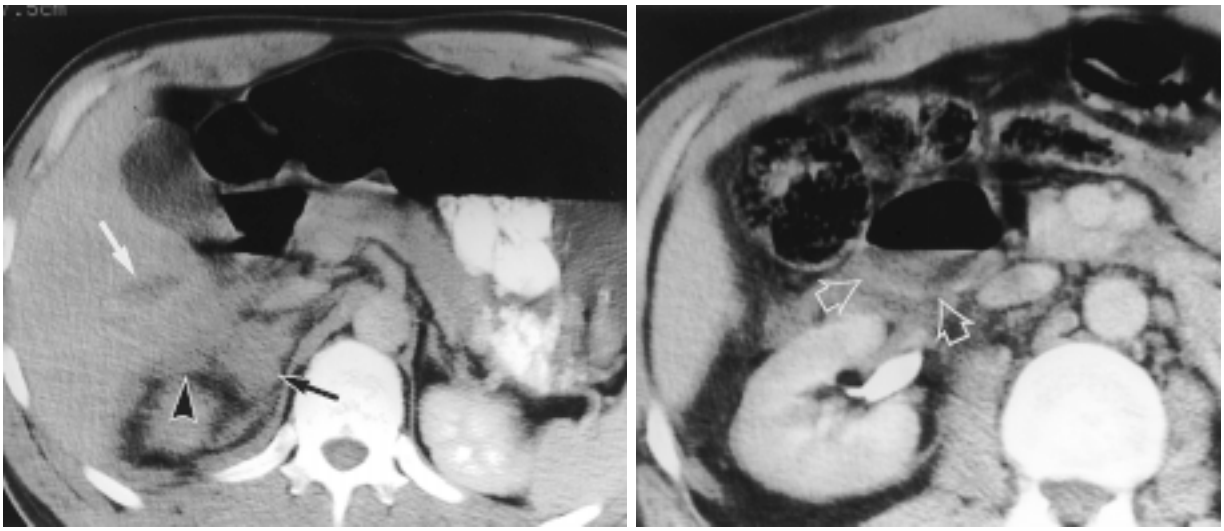
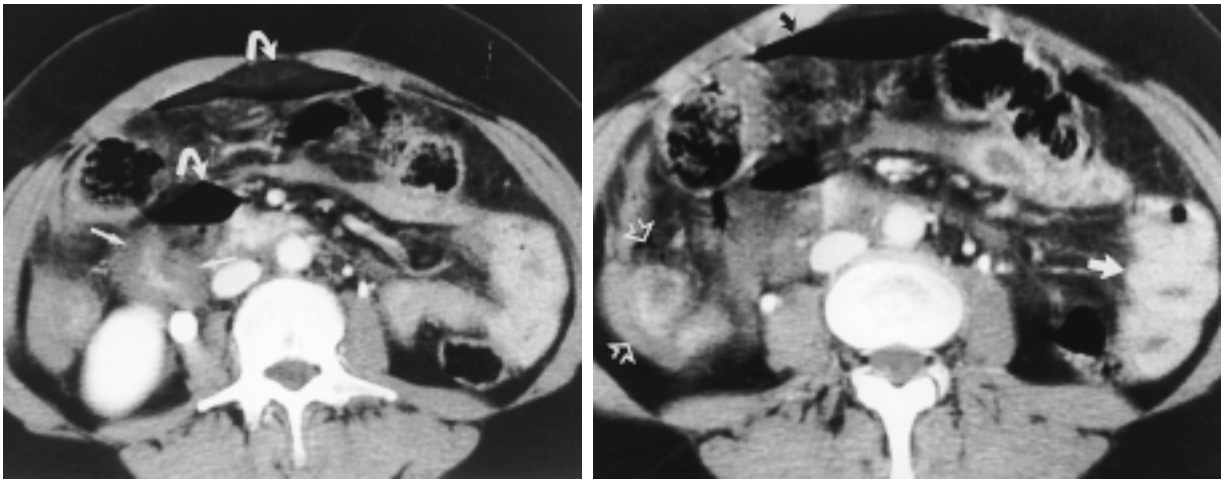


Figure 11. Intraperitoneal bladder rupture and mesenteric lacerations in a 29-year-old man. CT scan demonstrates free contrast material (black arrows) from an intraperitoneal bladder rupture that masks evidence of mesenteric bleeding. Contrast material extends into the subcutaneous tissue (white arrows) through a rupture at the origin of the oblique muscles.



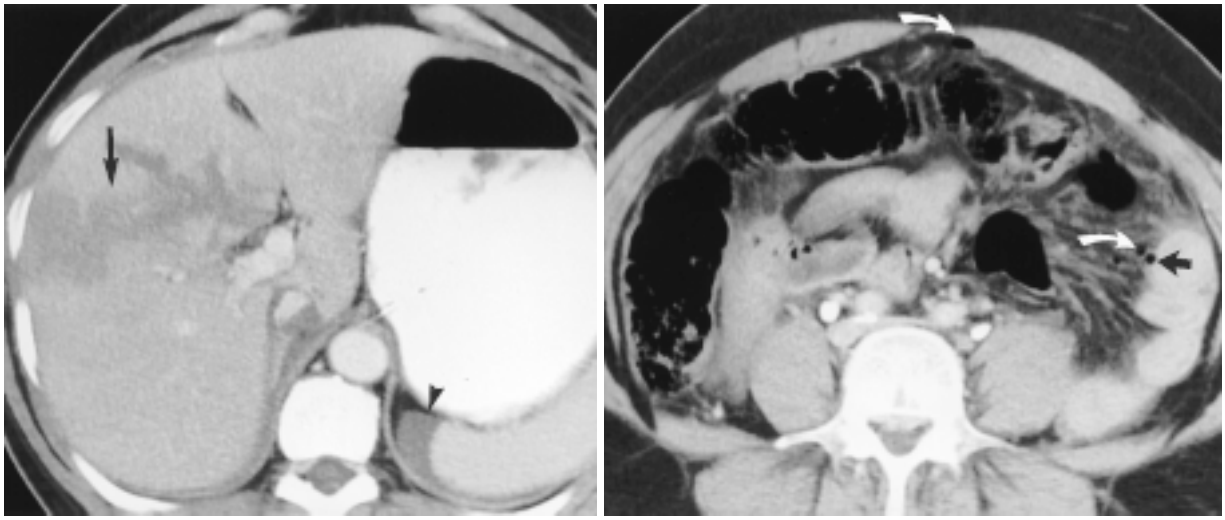
a. **b.**

Figure 12. Contusion of the second portion of the duodenum, right adrenal hematoma, and intraparenchymal liver laceration in a 36-year-old man. **(a)** Abdominal CT scan demonstrates an intraparenchymal liver laceration (white arrow) and adrenal hematoma (black arrow), with surrounding retroperitoneal blood (arrowhead). **(b)** On a CT scan obtained at a lower level, periduodenal hematoma thought to be from the other injuries masks the duodenal injury (arrows), which could be suspected on the basis of its ill-defined wall and adjacent blood.



a. **b.**

Figure 13. Transection of the second portion of the duodenum and full-thickness perforation of the right colon in a 46-year-old woman. **(a)** Abdominal CT scan reveals a thick-walled and ill-defined duodenum (straight arrows) and free and retroperitoneal air (curved arrows), findings that suggest duodenal injury. (**b**) Another CT scan obtained at a lower level shows air and fluid (open arrows) adjacent to the right colon. These findings were thought to be associated with the duodenal injury because both the duodenum and right colon reside in the anterior pararenal space. Black arrow indicates free air. The thick-walled jejunum (solid white arrow) was normal at surgery.



a. b.

Figure 14. Distal jejunal perforation, mesenteric hematoma, and liver laceration in a 51-year-old woman. **(a)** Abdominal CT scan shows a large liver laceration (arrow) with hemoperitoneum (arrowhead). **(b)** On a CT scan obtained at a lower level, subtle collections of intramural air (black arrow) and intraperitoneal air (white arrows) in the region of the thick-walled jejunum were not appreciated.

Factors other than those related to the imaging appearance of injury can affect diagnostic accuracy. Specific reasons include an often chaotic trauma setting that may cause findings to be overlooked or misinterpreted (Fig 14) and the presence of other injuries that may distract the observer (Fig 15). It has been found that a finding on a radiologic study is more likely to be missed if another imaging finding is identified first (30). Large patients and metallic monitoring or support devices can cause significant artifact (Fig 16).

Conclusions

Treatment algorithms weighted toward conservative management amplify the need to identify bowel trauma early in the treatment process. Most injuries are readily detected, but others are more subtle and require careful evaluation and interpretation. Extraluminal air and oral contrast material and intramural air are virtually pathognomonic of bowel injury. Thickened bowel wall is a subjective but useful sign that may indicate not only bowel but also mesenteric injury. Intravenous contrast material extravasation in the mesentery is a sure sign of laceration whereas mesenteric stranding is less helpful. Free intraperitoneal fluid, especially in an interloop location, should raise the suspicion for bowel or mesenteric injury even in the presence of solid organ laceration. Despite diligent effort, some abnormalities will escape detection.

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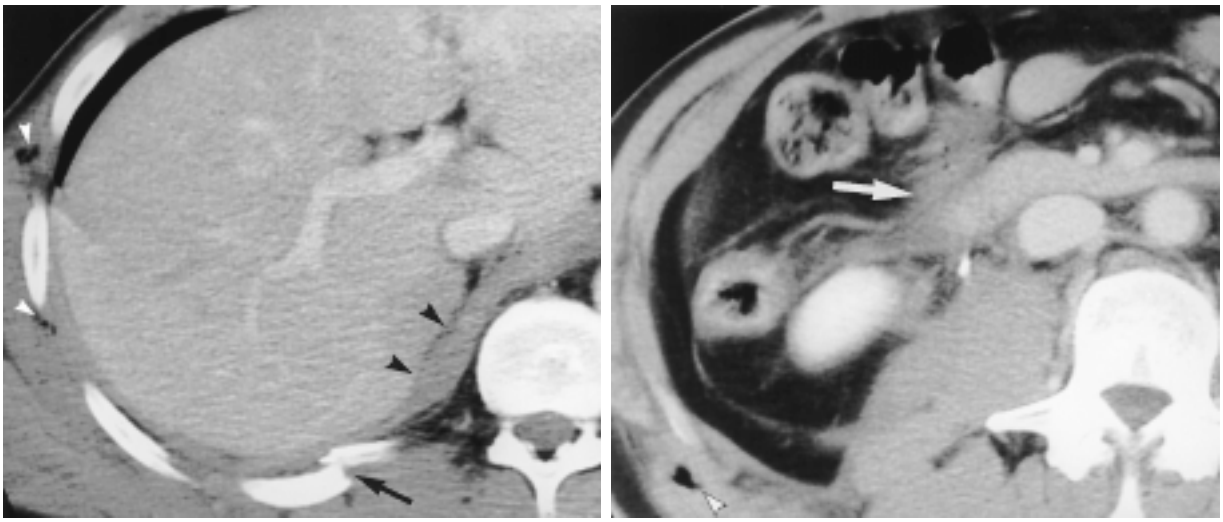

a. **b.**

Figure 15. Right diaphragmatic rupture and duodenal contusion in a 43-year-old man. **(a)** Abdominal CT scan shows a posterior right rib fracture (arrow) at the site of a diaphragmatic hematoma (black arrowheads). **(b)** On a CT scan obtained at a lower level, extension of the diaphragmatic hematoma into the posterior pararenal space (arrow) was erroneously thought to be the source of the periduodenal hematoma in the anterior pararenal space. Subcutaneous air (white arrowheads in **a** and **b**) from barotrauma is visible.

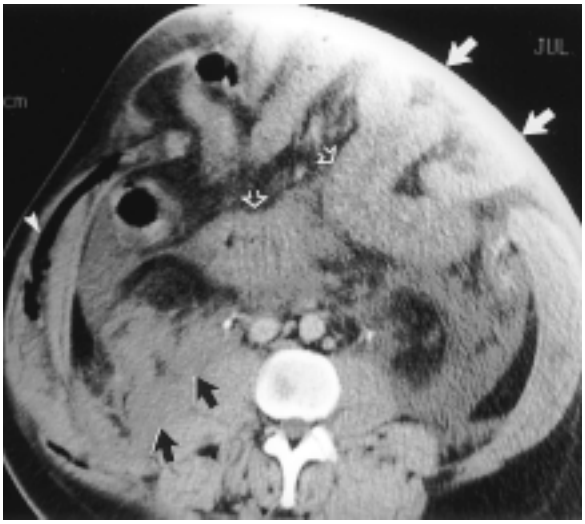

Figure 16. Multiple mesenteric and serosal jejunal tears in a 43-year-old man. CT scan shows thick-walled small-bowel loops (open arrows) that are partially obscured by an extraneous artifact (solid white arrows). The retroperitoneal hematoma (black arrows) is related to a renal laceration (not shown). Air between the internal and external oblique muscles (arrowhead) is related to barotrauma.

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