17 Bowel and Mesenteric Injury

Viola Valentini, Grazia Loretta Buquicchio, Ginevra Danti, Michele Galluzzo, Stefania Ianniello, Margherita Trinci, and Vittorio Miele

17.1 Introduction

Bowel and mesenteric injuries are found in approximately 1.2–5% of patients following blunt abdominal trauma [1–4]. Despite their infrequency, the clinical significance of these lesions cannot be underestimated. The gastrointestinal tract represents the third most commonly involved abdominal organ in blunt trauma, after spleen and liver. Mesenteric injuries are reported to be about three times more frequent than bowel perforations [3, 5, 6].

Clinical diagnosis of blunt and mesenteric injuries is difficult because of scarce specificity of laboratory findings and delayed onset of peritoneal irritation signs. The classic triad of abdominal pain, guarding, and decreased or absent bowel sounds occurs only in one-third of patients [7]. Moreover, physical examination and abdominal assessment may be limited and unreliable in a trauma setting, due to significant neurologic comorbidities.

Contrary to the trend of nonoperative management of solid intra-abdominal organs, the treatment of choice for significant bowel and mesenteric injuries remains early surgery. A delay in diagnosis and treatment, as little as 5–8 h, results in increased complications and mortality rate [8, 9], with mortality rates as high as 30% if the delay is 24 h or more [3, 9]. A prompt and accurate diagnosis is therefore critical in preventing fatal complications and reducing mortality rates (mostly septic and hemorrhagic) in bowel traumatic injuries, but it is inadequately supported and hardly achieved by clinical examination and other commonly used diagnostic tests, such as diagnostic peritoneal lavage (DPL) and focused assessment with sonography in trauma (FAST scan) [4, 10]. Currently, due to major advancements in technology, multidetector computed tomography (MDCT) has emerged as a critical diagnostic tool, becoming the imaging modality of choice to evaluate abdominal trauma in hemodynamically stable patients.

The role of imaging is, therefore, of great importance: the radiologist is asked not only to detect signs of intestinal and mesenteric traumatic injuries but also to indicate the clinical significance of such lesions, trying to identify those requiring an immediate operative treatment (major injuries), substantially represented by intestinal perforation, active bleeding, and vascular avulsion of the mesentery, that can rapidly result in septic,

V. Valentini, M.D. (✉) • G.L. Buquicchio
M. Galluzzo • S. Ianniello • M. Trinci
Department of Emergency Radiology, S. Camillo Hospital, C.ne Gianicolense, 87, 00152 Rome, Italy
e-mail: violavalentini@libero.it

G. Danti • V. Miele
Department of Radiology, Careggi University Hospital, Florence, Italy

V. Miele, M. Trinci (eds.), *Diagnostic Imaging in Polytrauma Patients*,
https://doi.org/10.1007/978-3-319-62054-1_17

hemorrhagic, and ischemic complications [11–14], and to distinguish them from those (minor injuries), such as bowel wall contusion, mesenteric infiltration, and non-bleeding mesenteric hematoma, that can be managed nonsurgically.

17.2 Mechanisms of Blunt Bowel and Mesentery Injury

Mostly due to motor vehicle accidents, bowel and mesentery injuries have registered an increase in incidence after the introduction of seat belts [5, 15, 16]. Other common causes include assaults, occupational accidents, sports, and falls. In general terms, the incidence and significance of gastrointestinal trauma is higher in childhood because of the incomplete development of the abdominal wall musculature.

Three main pathogenic mechanisms have been described to be responsible for causing bowel and mesentery lesions in blunt trauma (Fig. 17.1), which may act isolated or combined:

1. Crush: direct force applied to the bowel wall, causing compression between the spine and the abdominal wall.
2. Shear: rapid deceleration producing a shearing force between fixed and mobile portions of the bowel.
3. Burst: sudden increase in intraluminal pressure causing perforation. The bowel bursts when the intraluminal pressure exceeds the bowel wall tensile strength.

Crushing may determine local lacerations of the bowel wall and mesentery, mural and mesenteric hematomas, localized devascularization, and full-thickness contusions. Susceptibility to crush injuries increases with age, in relation to the relaxation of abdominal musculature. Because of their anatomical features (close contact to the spine), the duodenum and transverse colon are particularly susceptible to this type of injury [17], which are often caused by seat belt, steering wheel or, mostly in pediatric age, bicycle handlebar.

Shearing forces can lead to bowel lacerations, mesenteric tears, and interruption of the mesenteric vessels. Points of anatomical fixity, or intestinal segments close to acquired fixity points, such as bridles and adhesions, are more susceptible to these injuries.

The presence of a “seat belt mark” sign, characterized by patterned ecchymosis or abrasion across the patient’s abdominal wall, correspondent to the position of the diagonal or horizontal strap of the seat belt, is considered a reliable predictor of bowel injury [11, 18]. A radiologic seat belt sign, consisting of increased attenuation in the subcutaneous fat over the abdomen, has been described [16]. At impact, the seat belt compression may close off the bowel, causing a sudden increase of the intraluminal pressure in the “closed loop” that may result in bursting injuries. When the intraluminal pressure reaches 120–140 mmHg, either a single perforation or multiple small perforations of the bowel wall can occur, usually on the antimesenteric border of the loop [15, 16]. Requiring less energy to occur than

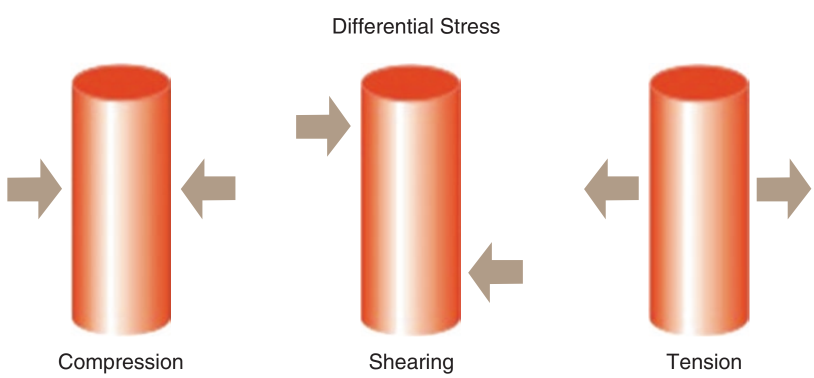

Fig. 17.1 Scheme of the three types of stress that act on bowel and mesentery in abdominal blunt trauma

injuries from the crush and shearing mechanisms, burst lesions are therefore more likely to be isolated (not associated with other injuries) [16]. Pre-existing pathological conditions, such as ileus, Crohn disease, and bowel obstruction, predispose the bowel to this type of injury.

17.3 Anatomo-Pathological Considerations

The small bowel is the most often injured intestinal tract (70%) in blunt abdominal trauma. As already mentioned, intestinal tracts close to fixed point of attachment, such as proximal jejunum near the ligament of Treitz and distal ileum near the ileocecal valve, where mobile and fixed portions of the gut are contiguous, are particularly exposed to damage [19, 20].

The colon accounts for 20% of intestinal traumatic injuries. The ascending and descending colon, fixed and partially retroperitoneal, are generally susceptible to more severe injuries compared to the more mobile transverse and sigmoid colon. Injuries to the right colon are always associated with multiple injuries elsewhere, reflecting the high-energy dissipation required to inflict them [21, 22] (Fig. 17.2). The sigmoid colon is at risk of closed loop perforation. Due to its exposed location, the transverse colon is reported to be the most vulnerable portion of the large bowel, but its relative mobility accounts for the minor entity of most injuries at this site.

Duodenum represents the intestinal tract less frequently involved in blunt trauma (10%). Its anatomical features (mainly retroperitoneal organ, in direct contact with the thoracic spine) explain the peculiarity of diagnostic findings in cases of perforation and the frequent association with pancreatic injury.

Injuries to the appendix, stomach, and rectum are extremely uncommon. Rectum injuries are often associated with major pelvic fractures.

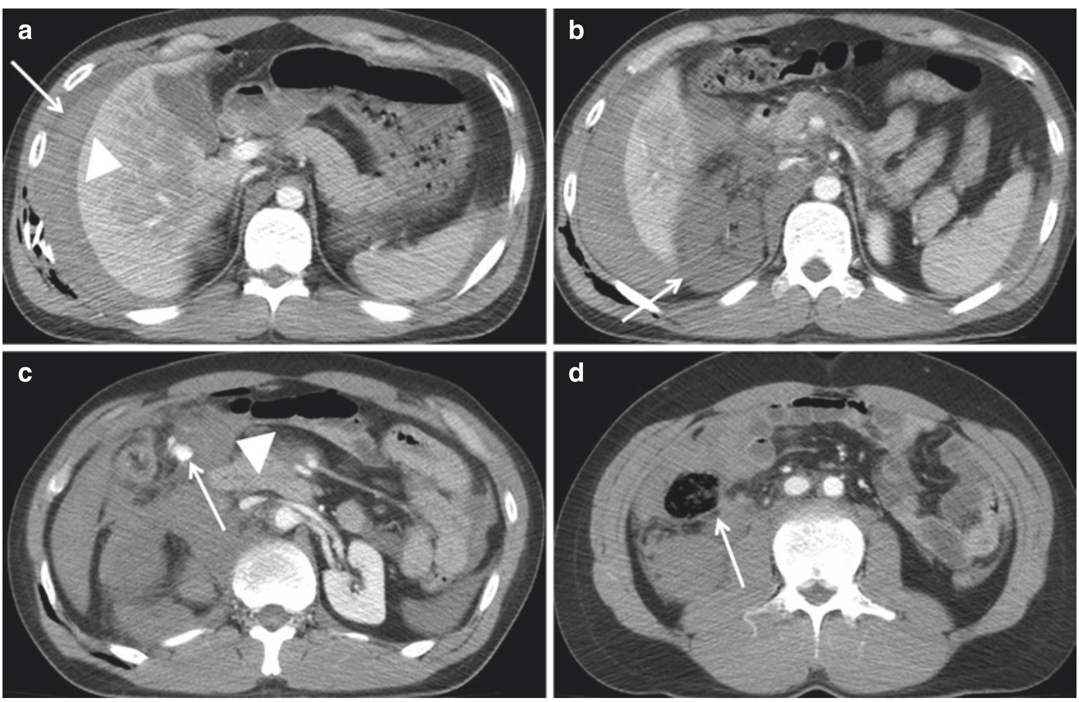

Fig. 17.2 High-energy blunt abdominal trauma. Axial CT images show rib fractures (*curved arrow* in **a**), hemoperitoneum (*arrow* in **a**) and hepatic contusion (*arrowhead* in **a**), devascularization of the right kidney (*arrow* in **b**), mesenteric hematoma (*arrowhead* in **c**) with contrast material extravasation (active bleeding) (*arrow* in **c**), and unenhanced ascendant colon wall (*arrow* in **d**)

Table 17.1 Bowel and mesentery major and minor injuries

Bowel	Mesentery
Significant (major) injuries	
Complete tear of the bowel wall	Active bleeding
Bowel ischemia	Mesentery disruption
	Mesenteric injury with bowel ischemia
Not significant (minor) injuries	
Serosal tear of the bowel wall	Mesenteric hematoma (no bleeding)
Bowel hematoma	Mesenteric stranding

The site of damage correlates well with prognosis, accounting the amount and quality of bowel content, which is less enzymatically active and has low pH and bacterial counts in case of small bowel lesions and more contaminating in case of colonic lesions. Intraperitoneal blood is a minor peritoneal irritant.

Bowel and mesenteric injuries are frequently associated with abdominal solid organ lesions [23] or spine and pelvic bones fractures [24].

The management of bowel and mesenteric traumatic injuries depends on the location and the type of damage. Surgical treatment is not always necessary and depends on the relevance of the lesion: major and minor injuries can be distinguished (Table 17.1). Surgically significant injuries, or "major" lesions, include a complete tear of the bowel, devascularized bowel, active mesenteric bleeding, and mesenteric injury associated with bowel ischemia.

Minor injuries include serosal tear of the bowel wall, bowel hematoma, mesenteric hematoma without active bleeding and mesenteric stranding; these conditions can be managed conservatively.

17.4 The Role of MDCT

Since diagnosis based on clinical findings has low sensitivity and is often unreliable, a set of diagnostic tools has been used to evaluate patients in whom abdominal injury is suspected, including DPL, FAST scan, and CT [4, 25].

DPL, traditionally used in several countries, is fairly sensitive (90%) for the detection of hemoperitoneum, but has several limitations: it is poorly specific in assessing the site and the extent of the damage, it is not reliable in detecting retroperitoneal injuries and, like any invasive procedure, it carries some risk of iatrogenic injuries [4, 10]. The use of results of DPL as the sole indication for surgery has led to a high nontherapeutic laparotomy rate.

FAST scan has a great sensitivity (86%) for the detection of free intra-abdominal fluid, but is nonspecific with regard to organ injury [4].

With a wide range of reported values for sensitivity and specificity (between 80–95% and 48–99%, respectively) [26], the accuracy of CT for detection of intestinal and mesenteric injuries due to blunt trauma has long been controversial. Until the 2000s, surgical literature described CT as unreliable in distinguishing surgical from not-surgical bowel and mesenteric injuries. The recent introduction of MDCT significantly decreased the time taken to perform the examination, decreased the motion artifacts, and improved the blood vessel opacification and solid organ enhancement. Providing a wide spectrum of findings suggestive of bowel and mesenteric injuries, MDCT is more sensitive and specific than DPL, FAST scan, and clinical examination [19]. Owing to the great advances in CT technology and improvement in interpretation, MDCT has currently become the diagnostic tool of choice in the evaluation of blunt abdominal trauma in hemodynamically stable patients [6, 27].

17.5 MDCT Technique

All MDCT examinations must be performed with a high-resolution protocol, with reconstruction interval values equals to 1 mm, and completed with coronal and sagittal multiplanar reconstruction in the post-processing elaboration.

The acquisition of pre-contrast CT abdomino-pelvis scans is useful to identify free air collections, to detect abnormal attenuation of mesenteric fat, and to assess the attenuation values of any fluid collection and/or of the bowel wall.

A biphasic study in arterial and venous phase after the intravenous infusion of 120–150 ml of iodinated contrast material at an adequate rate (≥3 ml/s) is indicated to detect active bleeding and identify perfusion abnormalities in the bowel loops. In suspicious of low-flow vascular active bleeding, a delayed phase (3–5 min) may be added to the examination [11, 28].

Many investigators have proven that administration of oral contrast material is not routinely required in the MDCT evaluation of patients with blunt abdominal trauma [4, 29–31]. Being time-consuming, oral contrast material administration increases the risk of vomiting and aspiration without improvement of diagnostic capability [32].

17.6 MDCT Findings of Intestinal and Mesenteric Injury

According to surgical and prognostic criteria, traumatic injuries of the bowel and mesentery can be classified into "major" and "minor." Major lesions, including bowel perforation, active mesenteric bleeding, and mesenteric injury associated with bowel ischemia, require a surgical treatment. If unrecognized, these injuries may result in high morbidity and mortality, related to sepsis or hemorrhage. Minor lesions, including bowel wall tear limited to the serosa, bowel wall hematoma, and mesenteric hematoma without active bleeding, can be treated conservatively.

Currently, there are several recognized CT features of blunt bowel and mesenteric injury (Tables 17.2 and 17.3). Based on radiological criteria, we distinguish specific (direct) and nonspecific (indirect) bowel and mesenteric injury signs. Getting familiar with the appearance of specific and nonspecific signs is crucial to making a prompt and accurate diagnosis [4].

17.7 MDCT Findings of Bowel Injury

17.7.1 Bowel Wall Discontinuity

Detection of a discontinuous bowel wall is the most specific sign of bowel injury, with 100% specificity [4]. However, this finding is extremely uncommon on MDCT images and it has a very low sensitivity (5–10%) [23]. The relative infrequency of direct visualization of bowel perforation is mainly due to the small size of discontinuities [4]. The type of lesion may also influence the possibility of detection: blowout perforations are harder to identify on CT than lacerations because of the collapsing, cockade shaped, margins of the small hole. Site of perforation is important as well: a lesion occurring on the antimesenteric equatorial border of the loop may be easier to identify on axial scans (Fig. 17.3); lesions involving the superior or inferior wall will be better detected on multiplanar reconstruction. Lesions of the bowel wall are better depicted in the portal venous phase scan [11]. The distribution of free air may be useful in localizing the point of bowel rupture [28].

Table 17.2 MDCT signs of bowel injury

Specific (direct signs)	Nonspecific (indirect signs)
Bowel wall discontinuity	Bowel wall thickening
Extraluminal air	Abnormal bowel wall enhancement
Intramural air	Intraperitoneal/retroperitoneal fluid

Table 17.3 MDCT signs of mesenteric injury

Specific (direct signs)	Nonspecific (indirect signs)
Active bleeding	Mesenteric infiltration
Beading/termination of mesenteric vessels	Intraperitoneal fluid (mesenteric fluid collections)
Mesenteric hematoma	

17.7.2 Extraluminal Air

The presence of extraluminal air has a reported specificity of 95% and a sensitivity of 30–60% for bowel perforation [23]. Pneumoperitoneum or so-called "free air" is not necessarily detectable on CT scans at admission and may be apparent only at later examinations, obtained after 6–12 h. In cases of small bowel perforation, only minimal amount of free air is present.

Pneumoretroperitoneum seems to be a more sensitive finding of perforation of one of the retroperitoneal intestinal tracts: second to fourth portion of duodenum, ascending and descending colon [31].

Although bowel perforation is a major cause of this sign, extraluminal air may also be observed in the absence of bowel perforation [32]. Other possible sources of free air in the abdomen are diffusion of a pneumothorax in patients with diaphragmatic injury, barotrauma, mechanical ventilation, and chest tube placement. Small amounts of air can penetrate through the female genital tract. Intraperitoneal rupture of bladder with Foley catheter in place can cause pneumoperitoneum as well. Mimicking true pneumoperitoneum, the presence of air confined between the inner layer of the abdominal wall and the peritoneum parietal layer, so-called "pseudopneumoperitoneum," represents a potential diagnostic pitfall [4, 11].

However, the presence of free air in association with coexistent ancillary signs, such as bowel wall thickening, abnormalities of parietal enhancement, free fluid, and mesenteric infiltration, is highly predictive of bowel injury.

Using wide window settings (lung or bone windows) to review CT images aids in detecting small amounts of free abdominal air. Free air from bowel rupture commonly tends to extend behind the anterior abdominal wall, under the anterior parietal peritoneal layer, and along the anterior surfaces of liver and spleen (Fig. 17.4). However, foci of air may also be seen at the porta hepatis or in the mesenteric and portal venous system (Fig. 17.5). Extraluminal air can also be seen trapped in the mesentery (Fig. 17.6a), if the bowel wall discontinuity occurs on the mesenteric border**,** or located in the retroperitoneum, in case of duodenal, ascending and descending colon traumatic perforation (Fig. 17.6b).

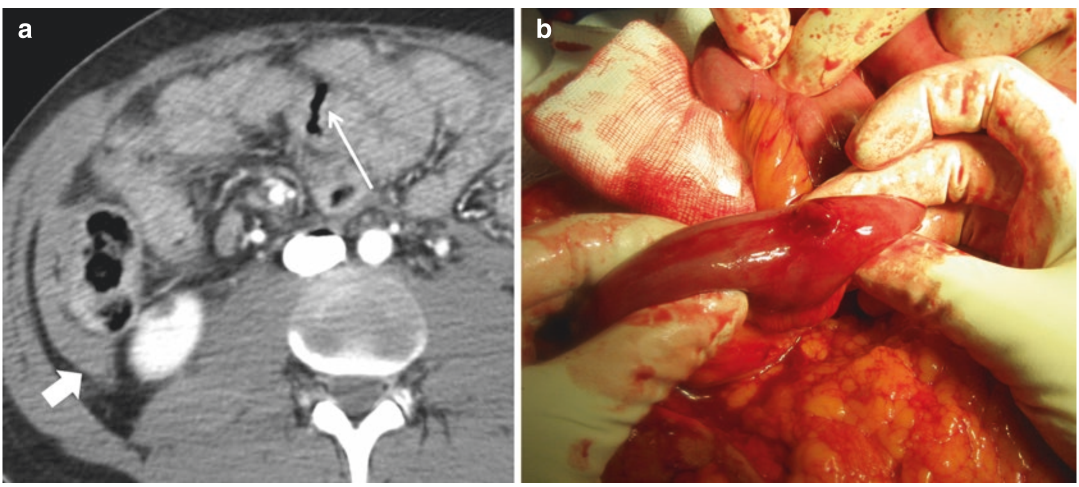

Fig. 17.3 Discontinuous bowel wall. (**a**) Axial CT contrast-enhanced image shows a wall discontinuity (*arrow*) on the anterior, antimesenteric wall of a small bowel loop, with extraluminal air and hemoperitoneum (*thick arrow*). (**b**) Intraoperative photograph of an antimesenteric small bowel wall perforation. Intraoperative image courtesy of Dr. Ennio Adami, MD

17.7.3 Intramural Air

Major and minor bowel injuries have findings of bowel wall thickening and free fluid in common. Along with extraluminal air, the presence of air bubbles confined in the thickness of the bowel wall (Fig. 17.7) increases the probability of a full-thickness injury, a major injury that requires laparotomy, rather a partial thickness injury, which can be treated conservatively [31].

17.7.4 Bowel Wall Thickening

Seen in 75% of transmural injuries, focal bowel wall thickening seems to be more sensitive for

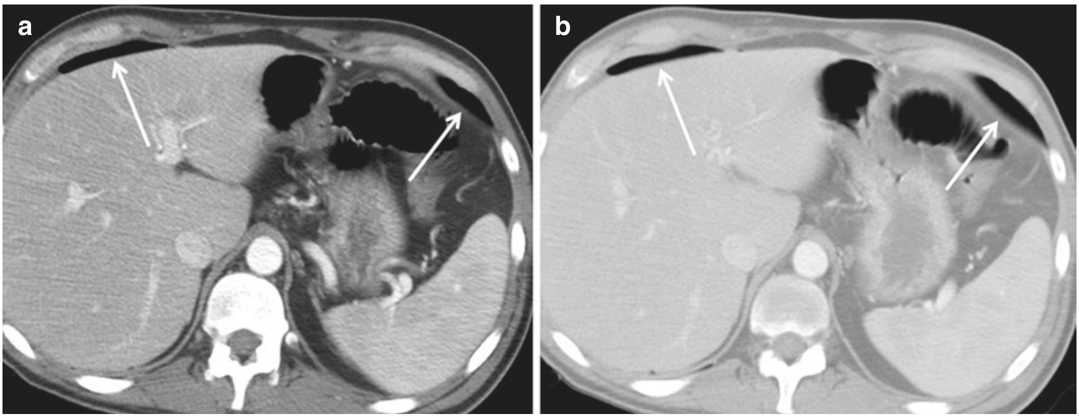

Fig. 17.4 Axial CT contrast-enhanced scan shows free air from bowel rupture laying behind the anterior abdominal wall, along the anterior surfaces of liver and spleen (*arrows* in **a**). Viewing the CT image in a bone window (**b**) better demonstrates the presence of small amounts of extraluminal air collections

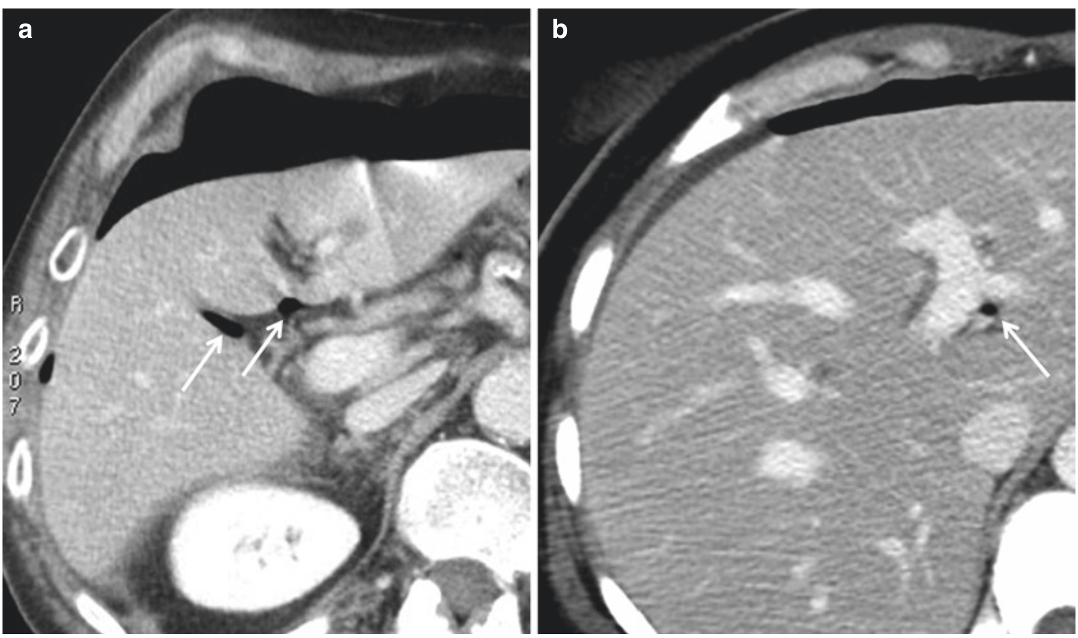

Fig. 17.5 Axial CT scans show air foci at the porta hepatis (*arrows*) (**a**). Axial CT scans show focal air bubble collecting in the portal venous system (*arrow*) (**b**)

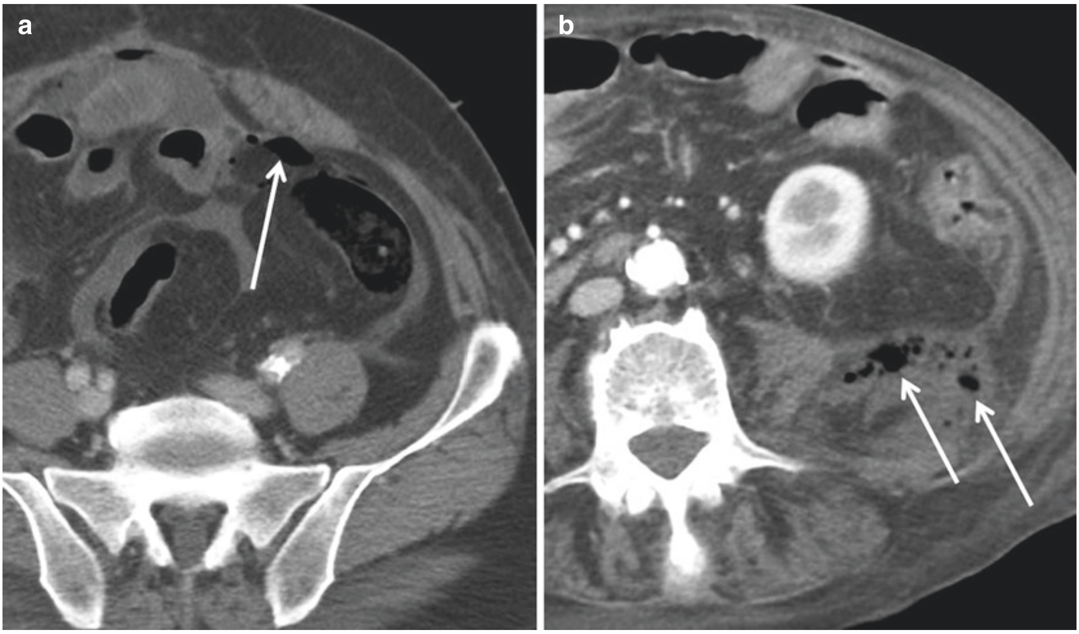

Fig. 17.6 Axial CT contrast-enhanced scans show air foci trapped in the mesentery (*arrow* in **a**). Free air in the retroperitoneum (*arrows* in **b**)

bowel injury than pneumoperitoneum [30–35]. This sign has a reported specificity of 90%, but is relatively insensitive, with reported values ranging 55–75% [36]. To minimize subjectivity in the evaluation of this sign, many authors suggest considering abnormal a disproportionate circumferential thickening of the bowel wall compared with normal appearing segments (Fig. 17.8) or a bowel wall thickness greater than 3 mm for the small bowel and 5 mm for the colon with adequate bowel distension. Focal bowel thickening can also be the expression of a partial thickness bowel injury. Intramural hematoma is a known evidence of blunt traumatic injury. Frequently localized to the duodenum (Fig. 17.9), uncommon in the large bowel, it is generally treated conservatively and tends to spontaneous resolution. Delayed complications such as stricture and obstruction are reported in some cases.

Diffuse small bowel wall thickening should not be confused with traumatic bowel injury. It commonly represents bowel edema, secondary to a systemic condition, such as hypoperfusion complex in so-called “shock bowel” (see below) or systemic volume overload from iatrogenic over-resuscitation [10].

Fig. 17.7 Axial CT contrast-enhanced scan shows foci of intramural air (*arrowhead*) in a thick-walled small bowel loop. Interloop fluid is also seen (*thin arrows*)

17.7.5 Abnormal Bowel Wall Enhancement

Bowel wall enhancement can be evaluated subjectively compared to the enhanced adjacent bowel loops; bowel wall density can be compared to that of the psoas muscle or of the contiguous vessels as well [28].

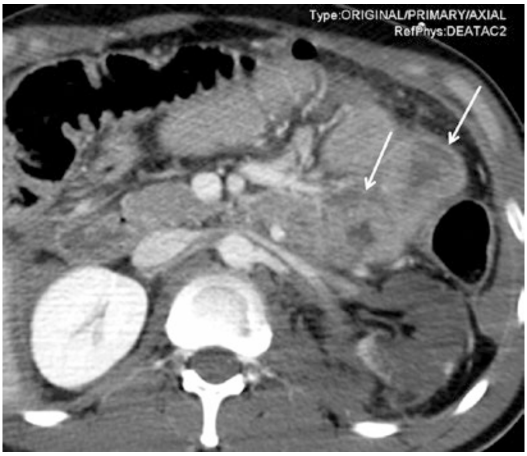

Fig. 17.8 Axial CT image shows small bowel loops with thickened wall and disomogeneous parietal enhancement. Left renal devascularization is also seen

Focal, patchy areas of increased enhancement of the bowel wall may represent bowel injury with vascular involvement [27]. However, areas of decreased or absent enhancement are indicative of ischemic bowel (Fig. 17.10).

Diffuse increased small bowel wall enhancement in the trauma setting has been described as a consequence of hypovolemic shock, in which intestinal hypoperfusion leads to increased permeability, with interstitial leakage of contrast material [34]. In shock bowel, abnormal parietal enhancement, characterized by intense mucosal enhancement and hypodense submucosal edema, is associated with wall thickening and fluid distension of the whole small bowel, likely related to unsuccessful reabsorption. Intestinal findings are usually associated with other findings of hypovolemic shock, such as increased enhancement of kidneys, adrenal glands and spleen and collapsed inferior vena cava [34] (Fig. 17.11). Hypoperfusion findings cannot be noted in large bowel.

Fig. 17.9 Duodenal hematoma. Coronal reformatted CT image shows a focal thickening of the duodenal wall (*arrow*) in the absence of retroperitoneal fluid or free air

Fig. 17.10 Coronal reformatted CT scan shows reduced parietal enhancement of small bowel ischemic loops in the left lower abdominal quadrant (*oval*)

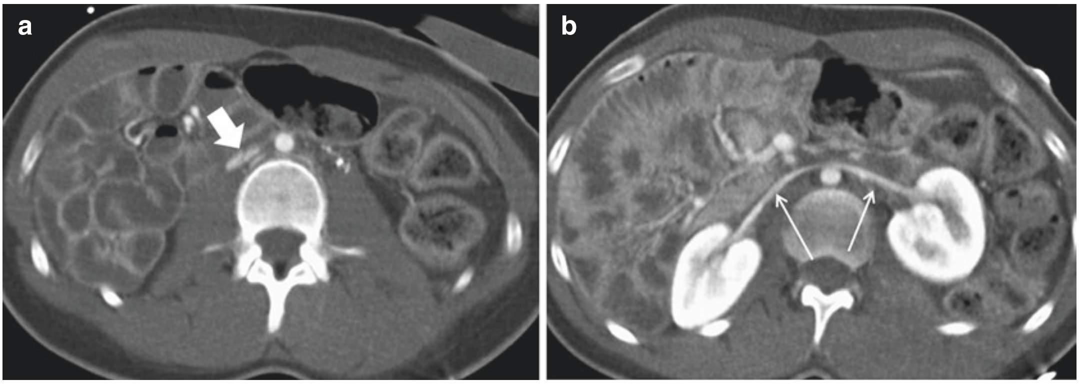

Fig. 17.11 Axial CT contrast-enhanced image shows diffuse hypervascular thickening of small bowel loops, with mucosal feathering, features characteristic of shock bowel. Flattened inferior vena cava (*thick arrow* in **a**) and renal veins (*thin arrows* in **b**) and increased enhancement of the kidneys (**b**) are noted

17.8 MDCT Findings of Mesenteric Injury

17.8.1 Mesenteric Hematoma

Mesenteric hematoma appears as a well-defined inhomogeneous collection of hemorrhagic fluid, with attenuation values varying depending on the degree of degradation of blood components, but, in general, closer to that of the soft tissues than that of fluids. Large mesenteric hematomas may exert mass effect on adjacent vessels and bowel loops. Although specific for mesenteric traumatic injury, in the absence of active extravasation, mesenteric hematoma is not an indication for operative treatment.

"*Sentinel clot sign,*" defined by focal, circumscribed high-density collection of clotted blood, with average CT density greater than 50 HU at basal scans [37], tending to accumulate adjacent to the site of bleeding, has been described as a clue to localize an hemorrhage source (Fig. 17.12).

Fig. 17.12 On unenhanced axial CT scan, *"sentinel clot sign"* appears as a focal, circumscribed high-density collection of clotted blood (*arrow*), adjacent to the site of bleeding

17.8.2 Active Bleeding

This finding has 100% specificity for the diagnosis of major mesenteric lesion.

In active mesenteric bleeding, the extravasation appears as high density contrast leak, with attenuation values close to that of an adjacent contrast-enhanced artery, surrounded by lower, disomogeneous attenuation hematoma in the arterial phase (Fig. 17.13); active bleeding usually shows increase in size and decrease in attenuation on delayed phases (Fig. 17.14).

Significant mesenteric bleeding requires urgent surgical exploration, both for stopping the hemorrhage and for investigating the bowel because of the risk of ischemia.

17.8.3 Beading and Termination of Mesenteric Vessels

Most recently recognized, this finding indicates a surgically important mesenteric injury [32].

Vascular beading is defined as focal alteration of the mesenteric vessels size, with the same attenuation of arteries during all the phases of the scan. It represents incomplete lesion of the vascular wall (pseudoaneurysm), contained by the serosa and surrounding tissues. A lack of continuity or tapering of a mesenteric artery or vein indicates irregular contour and abrupt termination of mesenteric vessels. Both signs have high specificity, ranging from 93 to 95%, but low sensibility, ranging from 45 to 50% [1, 4]. Due to the orientation of mesenteric vessels, this CT finding is better appreciated on coronal or sagittal reformatted images [32].

Fig. 17.13 Mesenteric bleeding. Axial CT scan in the arterial phase shows a large, disomogeneous mesenteric hematoma, containing high density contrast leak (*arrows*), with attenuation values close to that of an artery

17.9 MDCT Findings Coincident in Both Intestinal and Mesenteric Injury

17.9.1 Mesenteric Infiltration (Stranding)

Ill-defined, striated soft-tissue infiltration and haziness of mesenteric fat (Fig. 17.15), corresponding to microhemorrhagic foci, is a sensitive, but poorly specific sign, being commonly associated to other findings suggestive of mesenteric injury. Mesenteric stranding may be associated to bowel perforation as well [4, 31].

The coexistence of mesenteric infiltration with increased bowel wall thickness may be highly suggestive for a major intestinal injury, with ischemic sufferance of the bowel.

Pre-existing mesenteric stranding, as in inflammatory panniculitis, may mimic mesenteric traumatic injury. In inflammatory conditions, however, the fat stranding is well defined and multiple lymph nodes are associated.

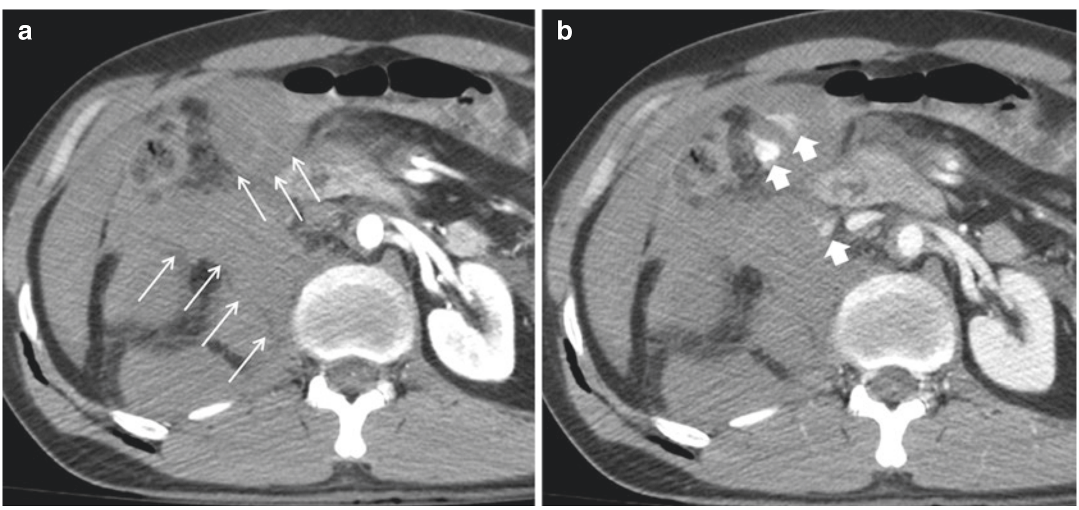

Fig. 17.14 Mesenteric bleeding. Axial CT scan in arterial phase shows multiple large mesenteric hematomas (*arrows* in **a**). Contrast extravasation within the mesenteric hematomas is clearly depicted in the portal phase CT (*thick arrows* in **b**)

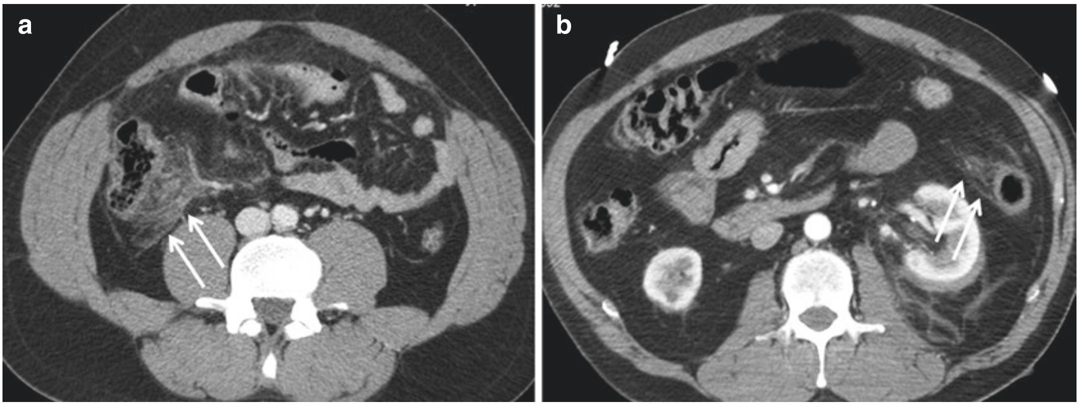

Fig. 17.15 Mesenteric stranding, appearing as ill-defined, striated soft-tissue infiltration of pericecal fat (*arrows* in **a**) and left paracolic gutter (*arrows* in **b**) on axial CT contrast-enhanced scans

17.9.2 Intraperitoneal or Retroperitoneal Fluid

The presence of free fluid is one of the most relevant signs of bowel and/or mesenteric injury.

The evidence of free fluid in the peritoneal/retroperitoneal recesses without concomitant CT scan evidence of traumatic lesion to solid organs seems to be suggestive of bowel or mesenteric injury [31], with a reported sensitivity of about 84% [8]. The combination of free fluid and free air increased the sensitivity for small bowel perforation to 97% [38]. On the other hand, the absence of intra/retroperitoneal fluid substantially rules out a significant bowel and/or mesenteric injury [1].

In the presence of free fluid without signs of any solid organ injury, is mandatory to search for other CT findings predictors of bowel injury.

The fluid may be of low attenuation, representing extravasated bowel contents, or of intermediate to high attenuation (30–50 UH), due to acute hemorrhage (hemoperitoneum).

The presence of a fluid-fluid level, with a dependent layer of high attenuation (sedimented red blood cells), occurring within a few hours, may help confirm the bloody nature of the fluid. Attenuation values should be interpreted with caution: hemoperitoneum may have lower density in a patient with a decreased hematocrit or if the hemorrhage is more than 48 h old.

False positives are possible: a small amount of fluid accumulation in the Douglas patch in a female patient is considered physiologic. Recent studies [32] reported the presence of small amounts of isolated pelvic fluid even in male patients, in the absence of bowel and/or mesenteric injuries. Notice that post-traumatic low-density intraperitoneal fluid may be urine in the case of intraperitoneal bladder rupture.

The location of the fluid may indicate the site of the injury: hemoperitoneum from solid organs injury (liver, spleen) starts near the site of injury and flows along expected anatomic pathways. It collects around the solid organs in the perihepatic and perisplenic spaces and migrates caudally toward the pelvis, passing through the paracolic gutters (Fig. 17.16). Hemorrhage from a bowel or mesenteric injury is typically trapped between the mesenteric leaves that surround intestinal loops (Fig. 17.17). The presence of triangular interloop fluid collections (Fig. 17.18a) should prompt a search for an intraperitoneal bowel and mesentery injury.

Retroperitoneal fluid tends to localize at the site of injury. The presence of fluid in the retroperitoneum commonly indicates injury of duodenum, ascending colon, and descending colon (Fig. 17.18b).

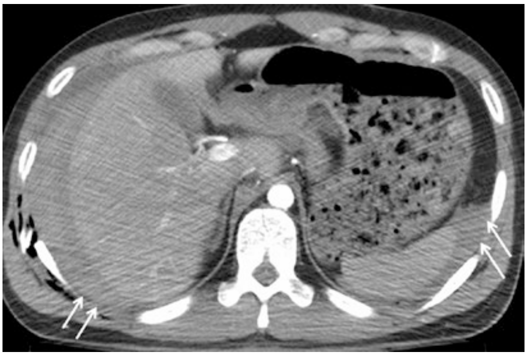

Fig. 17.16 Hemoperitoneum from solid organ injury. Axial contrast-enhanced CT scan shows hemoperitoneum in the perihepatic and perisplenic spaces (*arrows*). A rib fracture is also seen in the right hemithorax

Fig. 17.17 Axial CT contrast-enhanced scan shows interloop fluid (*curved arrow*). Mesenteric stranding (*oval*) and perihepatic fluid (*arrow*) are also seen

17.10 Associated Findings in Patients with Blunt Abdominal and Mesenteric Injury

In one-third of the patients, bowel and mesenteric injuries coexist with solid organs lesions.

As a general rule, the risk of hollow-organ injury increases with an increasing number of injured abdominal solid organs. When three abdominal solid organs are injured, the risk for bowel injury is 34%. The presence of lesions to abdominal solid organs should suggest an accurate detection of the contiguous abdominal territory, searching for additional bowel and mesentery injuries [28].

17.10.1 Pancreatic and Duodenal Injuries

Pancreatic injuries are relatively uncommon, found in 2–12% of patients with blunt abdominal trauma. They most commonly result from the direct impact on the upper part of the abdomen of the steering wheel or the handlebars, with compression of the pancreatic neck and body against the vertebral column. The close duodenopancreatic anatomic relationship explains why pancreatic injuries are associated to duodenal injuries in approximately 20% of cases [39].

Distinguishing among duodenal contusion, duodenal hematoma, and duodenal perforation is

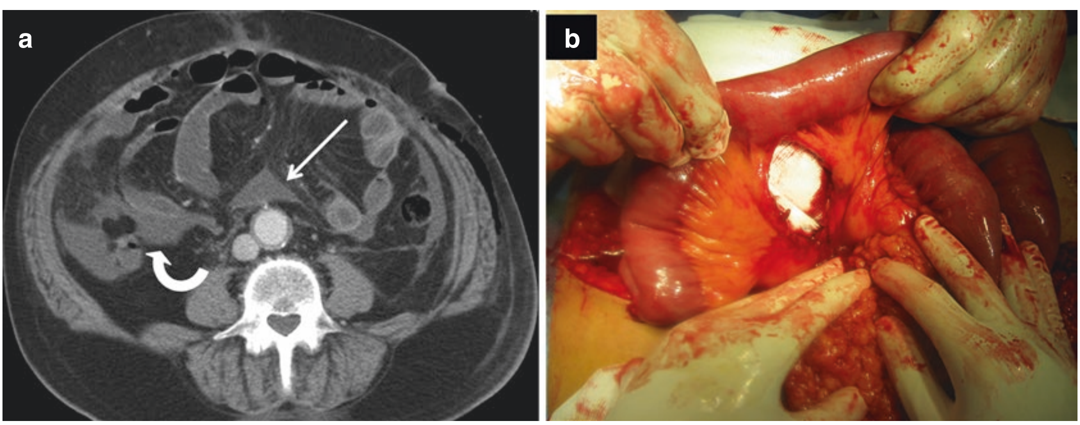

Fig. 17.18 Axial CT contrast-enhanced scan (**a**) shows triangular shaped fluid collection (*arrow*) and interloop fluid (*curved arrows*). Intraoperative image (**b**) shows a focal laceration of the mesentery. Intraoperative image courtesy of Dr. Ennio Adami, MD

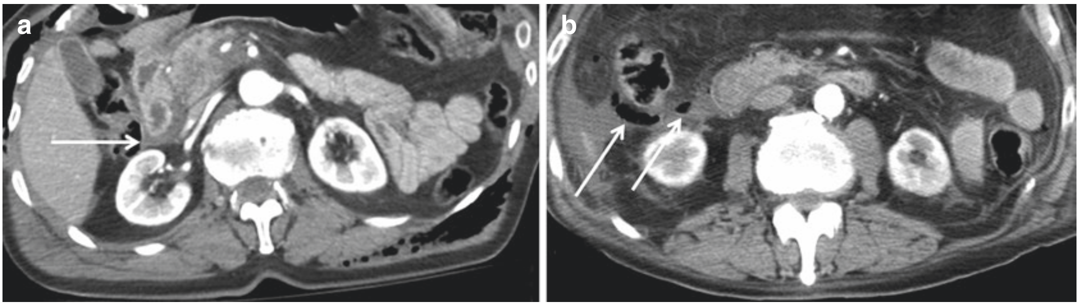

Fig. 17.19 (**a**) Axial CT contrast-enhanced scans show fluid in the right retroperitoneal space (*arrow*) in duodenal contusion. (**b**) The presence of free air in the right retroperitoneal space (*arrows*) suggests a retroperitoneal intestinal perforation

important, because management varies depending on the diagnosis. Whereas duodenal perforation is an acute surgical emergency, hematoma usually resolves in 1–3 weeks with no need of surgical intervention. At CT imaging, a thickening of the duodenal wall associated to retroperitoneal fluid in the right anterior pararenal space may be seen in both duodenal contusion and duodenal perforation. If discontinuity in the duodenal wall is not detected, the presence of extraluminal air in the anterior pararenal space is the most reliable finding for differentiating duodenal perforation from hematoma [40] (Fig. 17.19).

17.10.2 Fractures of the Spine

Often related with seat belt use, Chance fracture is a hyperflexion injury of the lumbar spine that involves distraction of the posterior elements. These unstable transverse fractures, characterized by disruption of the posterior and middle columns, are frequently associated with significant intra-abdominal injuries (40%). Bowel and mesentery, often in association, are the mostly injured abdominal organs in Chance fractures, particularly when the fracture has a burst-type component [41].

Conclusions

During the past decade, conservative management of hemodynamically stable blunt trauma patients, even in the presence of abdominal solid organ injuries, has become the standard of care. The concomitance of significant bowel or mesenteric injury, however, would make conservative treatment inappropriate and necessitate immediate operative treatment. Misdiagnosis of surgical bowel or mesenteric injury, in fact, often results in significant morbidity and mortality. Imaging assessment plays a crucial role for a timely diagnosis of bowel and mesenteric traumatic injuries, allowing a prompt and appropriate management of the injured patients. When specific findings of major bowel and mesenteric injuries are detected on CT, the patient should urgently undergo operative treatment. When only nonspecific findings of bowel and mesenteric injury are found on CT, correlation between radiologic and clinical findings is needed. If the patient is stable, serial clinical examination is needed and a CT scan follow-up at 8–12 h may be recommended [10].

The question of how to manage patients with blunt abdominal trauma who show small amounts of free fluid in the abdomen without evidence of solid organ injury is still a matter of debate [42]. Repeated physical examination and MDCT follow-up at 8–12 h is suggested. In such cases a minimally invasive surgical approach, as diagnostic laparoscopy, should be considered [43, 44].

References

1. Atri M, Hanson JM, Grinblat L, Brofman N, Chughtai T, Tomlinson G. Surgically important bowel and/or mesenteric injury in blunt trauma: accuracy of multidetector CT for evaluation. Radiology. 2008;249(2):524–33.
2. Killeen KL, Shanmuganathan K, Poletti PA, Cooper C, Mirvis SE. Helical computed tomography of bowel and mesenteric injuries. J Trauma. 2001;51(1):26–36.
3. Watts DD, Fakhry SM. Incidence of hollow viscus injury in blunt trauma: an analysis from 275,557 trauma admissions from the east multi-institutional trial. J Trauma. 2003;54(2):289–94.
4. Brofman N, Atri M, Hanson JM, Grinblat L, Chughtai T, Brenneman F. Evaluation of bowel and mesenteric blunt trauma with multidetector CT. Radiographics. 2006;26(4):1119–31.
5. Cox EF. Blunt abdominal trauma. A 5-year analysis of 870 patients requiring celiotomy. Ann Surg. 1984;199:467–74.
6. Scaglione M, de Lutio di Castelguidone E, Scialpi M, et al. Blunt trauma to the gastrointestinal tract and mesentery: is there a role for helical CT in the decision-making process? Eur J Radiol. 2004;50:67–73.
7. Rizzo MJ, Federle MP, Griffiths BG. Bowel and mesenteric injury following blunt abdominal trauma: evaluation with CT. Radiology. 1989;173:143–8.
8. Fakhry SM, Brownstein M, Watts DD, et al. Relatively short diagnostic delays (< 8 hours) produce morbidity and mortality in blunt small bowel injury: an analysis of time to operative intervention in 198 patients from a multicenter experience. J Trauma. 2000;48:408–14.
9. Malinoski DJ, Patel MS, Yakar DO, et al. A diagnostic delay of 5 hours increases the risk of death after blunt hollow viscus injury. J Trauma. 2010;69:84–7.
10. Cinquantini F, Tugnoli G, Piccinini A, et al. Educational review of predictive value and findings of computed tomography scan in diagnosing bowel and mesenteric injuries after blunt trauma: correlation with trauma surgery findings in 163 patients. Can Assoc Radiol J. 2017; doi:10.1016/j.carj.2016.07.003. S0846-5371(16)30091-2 [Epub ahead of print]
11. Iaselli F, Mazzei MA, Firetto C. Bowel and mesenteric injuries from blunt abdominal trauma: a review. Radiol Med. 2015;120:21–32.
12. Tan KK, Liu JZ, Go TS, et al. Computed tomography has an important role in hollow viscus and mesenteric injuries after blunt abdominal trauma. Injury. 2010;41(5):475–8.
13. Yegiyants S, Abou-Lahoud G, Taylor E. The management of blunt abdominal trauma patients with computed tomography scan findings of free peritoneal fluid and no evidence of solid organ injury. Am Surg. 2006;72(10):943–6.
14. Walker ML, Akpele I, Spence SD, et al. The role of repeat computed tomography scan in the evaluation of blunt bowel injury. Am Surg. 2012;78(9):979–85.
15. Christophi C, McDermott FT, McVey I, Hughes ES. Seat belt-induced trauma to the small bowel. World J Surg. 1985;9(5):794–7.
16. Bates DD, Wasserman M, Malek A, et al. Multidetector CT of surgically proven blunt bowel and mesenteric injury. Radiographics. 2017;37(2):613–25.
17. Hughes TMD, Elton C. The pathophysiology and management of bowel and mesenteric injuries due to blunt trauma. Injury. 2002;33:295–302.
18. Borgialli DA, Ellison AM, Ehrlich P, et al. Association between the seat belt sign and intra-abdominal injuries in children with blunt torso trauma in motor vehicle collisions. Acad Emerg Med. 2014;21(11):1240–8.
19. Hawkings AE, Mirvis SE. Evaluation of bowel and mesenteric injury: role of multidetector CT. Abdom Imaging. 2003;28:505–14.
20. Walker ML. Bowel injury. Minerva Chir. 2013;68(3):233–40.
21. Howell HS, Bartizal JF, Freeark RJ. Blunt trauma involving the colon and rectum. J Trauma. 1976;16:624–32.
22. Strate RG, Grieco JG. Blunt injury to the colon and rectum. J Trauma. 1983;23:384–8.
23. Castrillon GA, Soto JA. Intestinal and mesenteric trauma. Radiologia. 2011;1:51–9.
24. Anderson PA, Henley MB, Rivara FP, et al. Flexion distraction and chance injuries to the thoracolumbar spine. J Orthop Trauma. 1991;5(2):153–60.
25. Miele V, Di Giampietro I (2014) Diagnostic imaging in emergency. Salute e Società (2EN):127–138. doi: 10.3280/SES2014-002010EN
26. Landry BA, Patlas MN, Faidi S, et al. Are we missing traumatic bowel and mesenteric injuries? Can Assoc Radiol J. 2016;67(4):420–5.
27. Malhotra AK, Fabian TC, Katsis SB, et al. Blunt bowel and mesenteric injuries: the role screening computed tomography. J Trauma. 2000;48(6):991–8.
28. Romano S, Scaglione M, Tortora G. MDTC in blunt intestinal trauma. Eur J Radiol. 2006;59(3):359–66.
29. Allen TL, Mueller MT, Bonk RT. Computed tomographic scanning without oral contrast solution for blunt bowel and mesenteric injuries in abdominal trauma. J Trauma. 2004;56(2):314–22.
30. Stuhlfaut JW, Soto JA, Lucey BC. Blunt abdominal trauma: performance of CT without oral contrast material. Radiology. 2004;233(3):689–94.
31. Lee CH, Haaland B, Earnest A, Tan CH. Use of positive oral contrast agent in abdominopelvic computed tomography for blunt abdominal injury: meta-analysis and systematic review. Eur Radiol. 2013;23(9):2513–21.
32. Pinto A, Miele V, Schillirò ML, Nasuto M, Chianese V, Romano L, Guglielmi G. Spectrum of signs of pneumoperitoneum. Semin Ultrasound CT MR. 2016;37:3–9. doi:10.1053/j.sult.2015.10.008 Epub 2015 Oct 28.
33. Yu J, Fulcher AS, Turner MA, et al. Blunt bowel and mesenteric injury: MDTC diagnosis. Abdom Imaging. 2011;36:50–61.

34. Brody JM, Leighton DB, Murphy BL. CT of blunt trauma bowel and mesenteric injury: typical findings and pitfalls in diagnosis. Radiographics. 2000;20:1525–36.
35. Mirvis SE, Shanmuganathan K, Erb R. Diffuse small-bowel ischemia in hypotensive adults after blunt trauma (shock bowel): CT findings and clinical significance. AJR Am J Roentgenol. 1994;163:1375–9.
36. Levine CD, Gonzales RN, Wachsberg RH. CT findings in bowel and mesenteric injury. J Comput Assist Tomogr. 1997;21:974–9.
37. Faget C, Taourel P, Charbit J, et al. Value of CT to predict surgically important bowel and/or mesenteric injury in blunt trauma: performance of a preliminary scoring system. Eur Radiol. 2015;25(12):3620–8.
38. Shanmuganathan K, Mirvis SE, Sover ER. Value of contrast enhanced CT in detecting active hemorrhage in patients with blunt abdominal or pelvic trauma. AJR Am J Roentgenol. 1993;161(1):65–9.
39. Miller LA, Shanmuganathan K. Multidetector CT evaluation of abdominal trauma. Radiol Clin N Am. 2005;43:1079–95.
40. Linsenmaier U, Wirth S, Reiser M, et al. Diagnosis and classification of pancreatic and duodenal injuries in emergency radiology. Radiographics. 2008;28(6):1591–602.
41. Kukin J, Korobkin M, Ellis J, et al. Duodenal injuries caused by blunt abdominal trauma: value of CT in differentiating perforation from hematoma. AJR. 1992;160:1221–3.
42. Bernstein M, Mirvis SE, Shanmuganathan K. Chance-type fractures of the thoracolumbar spine: imaging analysis in 53 patients. AJR Am J Roentgenol. 2006;187(4):859–68.
43. Rodriguez C, Barone JE, Wilbanks TO, et al. Isolated free fluid on computed tomographic scan in blunt abdominal trauma: a systematic review of incidence and management. J Trauma. 2002;53:79–85.
44. Chersakov M, Sitnikov V, Sarkysian B. Laparoscopy versus laparotomy in management of abdominal trauma. Surg Endosc. 2008;22:228–31.