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Bowel and mesenteric injuries from blunt abdominal trauma: a review

Francesco Iaselli · Maria Antonietta Mazzei · Cristina Firetto · Domenico D'Elia · Nevada Cioffi Squitieri · Pietro Raimondo Biondetti · Francesco Maria Danza · Mariano Scaglione

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Abstract The bowel and the mesentery represent the third most frequently involved structures in blunt abdominal trauma after the liver and the spleen. Clinical assessment alone in patients with suspected intestinal and/or mesenteric injury from blunt abdominal trauma is associated with unacceptable diagnostic delays. Multi-detector computed tomography, thanks to its high spatial, time and contrast resolutions, allows a prompt identification and proper classification of such conditions. The radiologist, in fact, is asked not only to identify the signs of trauma but also to provide an indication of their clinical significance, suggesting the chance of conservative treatment in the cases of mild and moderate, non-complicated or self-limiting injuries and focusing on life-threatening conditions which may benefit from immediate surgical or interventional procedures. Specific and non-specific CT signs of bowel and mesenteric injuries from blunt abdominal trauma are reviewed in this paper.

F. Iaselli · M. Scaglione
Department of Diagnostic Imaging, Pineta Grande Medical Center, Via Domitiana, Km 30, 81100 Castel Volturno, Italy

F. Iaselli (✉)
118, Corso Umberto I, 80138 Naples, Italy
e-mail: francescoiaselli@hotmail.it

M. A. Mazzei · D. D'Elia · N. C. Squitieri
Diagnostic Imaging Section, Department of Medical, Surgical and Neuro Sciences, University of Siena, Siena, Italy

C. Firetto · P. R. Biondetti
Fondazione IRCCS, Dipartimento di Radiologia, Ospedale Maggiore Policlinico Mangiagalli e Regina Elena, 20122 Milan, Italy

F. M. Danza
Emergency Radiology Section, Department of Bioimaging and Radiological Sciences, Policlinico "A. Gemelli", Rome, Italy

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Introduction

The bowel and the mesentery represent the structures most frequently involved in blunt abdominal trauma (BAT) after the liver and the spleen [1–5].

The relative infrequency of such injuries, along with the limited ability of radiologists not sufficiently trained in the field of emergency to recognize their signs at imaging and the scarce specificity of the associated clinical signs and laboratory findings, explains the high rates of delayed and missed diagnoses. Delayed diagnosis of bowel and mesenteric injuries, by as few as 8 h, may result in severe complications and high mortality rates, mainly related to bleeding, peritonitis, and sepsis [6–8].

In the current era of non-operative management of patients with BAT, even in the case of injured parenchymal organs, role of imaging is, therefore, essential: actually, the radiologist is not only asked to detect signs of intestinal and mesenteric traumatic injuries but also to formulate a clinical degree of severity of such lesions, identifying those requiring an immediate operative treatment (angiography or surgery), substantially represented by intestinal perforation, active bleeding, and vascular avulsion of the mesentery, resulting in septic, hemorrhagic, and ischemic complications [9–11].

Anatomic considerations

The most common site of injury to the intestine in BAT is the small bowel (70 %) [12–14]. In particular, proximal jejunum near the ligament of Treitz, distal ileum near the ileo-cecal valve, intestinal segments close to bridles and adhesions are mostly exposed to damage being close to points of anatomical or constituted fixity, where mobile and fixed portions of the gut are contiguous and, therefore, susceptible to shearing force [13].

Colon injury from BAT is uncommon (20 %), being diagnosed in about 0.5 % of all major blunt traumas and in 10.6 % of patients undergoing laparotomy [14–16]. Most of colonic injuries are "partial-thickness" (only 3 % of patients undergoing laparotomy have "full-thickness" colonic tears). The ascending and descending colon, fixed, partially retroperitoneal segments, are generally exposed to more severe injuries compared to the transverse and the sigmoid colon, wrapped in their own meso and, therefore, characterized by a certain mobility.

The duodenum represents the structure less frequently involved in blunt intestinal and/or mesenteric trauma (BIMT, 10 %) [12–14]. Its anatomical features (mainly retroperitoneal organ, in close contact with the thoracic spine) explain the peculiarity of diagnostic findings in cases of perforation and the frequent association with signs of pancreatic injury (isolated duodenal lesions in adults are very rare).

Rapid deceleration represents the primary mechanism of duodenal injury from BAT, with visceral tearing at the junction of the intraperitoneal (free) and retroperitoneal (fixed) portions of the duodenum, such as between the third and fourth portions [1, 5].

Pathophysiology of injury

The leading cause of intestinal and/or mesenteric injury from BIMT is represented by road traffic accidents (RTA, 70–85 %) [4, 14, 17, 18], followed by aggressions and falls from heights.

With regard to RTA, an increase in intestinal and/or mesenteric lesions has been registered after the introduction of seat belts, which compress the intestinal loops at impact creating a "closed" hollow viscus and cause a sudden increase of the intraluminal pressure resulting in bursting injuries. The presence of a "seat belt mark" sign is not surprisingly considered a reliable predictor of bowel injury [19].

As a general rule, the incidence of BIMT is significantly higher in childhood, in relation to the incomplete maturation of the muscles of the abdominal wall; in this age group one of the most common causes of injury is represented by the impact of the bicycle's handlebar against the abdominal wall [20–22].

Pathogenic mechanisms at the basis of BIMT are substantially three, acting isolated or combined:

– a direct force may crush the gastrointestinal tract between the vertebrae and the anterior abdominal wall (as in the case of injuries by seat belt, bicycle handlebar or steering wheel);
– a rapid deceleration may produce a shearing force between fixed and mobile portions of the involved tract;
– a sudden increase in intraluminal pressure may result in bursting injuries (the loop bursts when the intraluminal pressure exceeds the wall tension) [14, 17, 23].

Clinical presentation

Clinical diagnosis of small bowel and colonic perforation in BAT is often challenging for several reasons:

– objective data are often non-specific and symptoms of peritoneal irritation are found in only half of the alert, non-comatose patients;
– clear clinical signs of peritonitis have late onset (may not appear for hours), especially in the case of traumatic perforation of the small intestine, whose content is characterized by neutral pH, low bacterial charge, and weak enzymatic activity;
– symptoms can be hidden or attenuated by concomitant injuries, as in the case of major trauma or neurological impairment due to involvement of the head or spinal cord, or by medications which can mask pain and guarding;
– the attention for suspicious signs from the gastro-intestinal tract can be reduced by coexisting, distracting lesions, such as a femur fracture [5–8].

Previous studies reported that using clinical assessment alone as the indication for laparotomy to treat bowel or mesenteric injuries is associated with a negative laparotomy rate that may be as high as 40 % [6, 7].

Laboratory findings

Low values of specificity have been also described for laboratory parameters used in the assessment of patients with BAT.

Several Authors consider diagnostic peritoneal lavage (DPL) more sensitive than CT in the identification of small bowel or colonic traumatic perforations [1, 6, 7, 12]. However this technique is limited, as well as by practical factors, by excessive sensitivity for injuries of intraperitoneal organs (even minor, self-limiting injuries may be emphasized), low specificity in assessing the site and the extent of the intraperitoneal damage and lack of sensitivity for traumatic perforations of retroperitoneal viscera.

Radiologic studies

Diagnostic imaging plays an important role in the recognition, evaluation, and follow-up of traumatic bowel and/or mesenteric injuries. The broad spectrum of the possible imaging findings is mainly related to the anatomical features of the affected organ, the type and intensity of the traumatic force, and the coexistence of lesions of other abdominal viscera [14, 18].

Conventional radiography (CR)

Identification of extraluminal free air in the case of traumatic perforation of a hollow viscus, and evidence of changes in caliber and tone of intestinal loops (so called "acute intestinal behaviors") [24] represent, to date, the only rationale for CR in the acute patient with suspected BIMT.

Ultrasonography (US)

At "F.A.S.T." assessment, now universally accepted as valid tool in the initial evaluation of the patient with suspected injury of the abdominal viscera, even small amounts of peritoneal fluid from bowel and/or mesenteric injury may be identified. Actually, this finding is non-specific in patients with suspected mesenteric and/or bowel traumatic injury: physiological conditions (e.g. women of child-bearing age), co-existing pathologies (e.g. liver failure) or traumatic injury of abdominal parenchymatous organs represent potential pitfalls [25].

The detection of focal-segmental thickening and abnormal echogenicity (e.g. from intramural hematoma) of the walls of an intestinal loop after a BAT is rare in the clinical practice, mainly because of anatomical factors (injuries of deep—retroperitoneal structures, for example, are scarcely recognizable at US), "sectoriality" of the examination, and lack of cooperation of the acute patient [25].

Computed tomography

In the vast majority of trauma centers, multi-detector computed tomography (MDCT) is now recognized as a primary tool in the diagnosis of traumatic injuries to the bowel and/or the mesentery in the stable and semi-stable patient (sensitivity and specificity values, respectively, between 64 and 95 % and 94 and 100 %), thanks to its high spatial and contrast resolutions and remarkable information content (combined assessment of hollow viscera and parenchymatous organs in a few seconds) [27–33]. Future routine use of 64-256-detector CT scanners would allow acquisition of isovoxel images and routine multiplanar viewing of images. In addition, faster acquisitions and the possibility of thinner sections can potentially improve the accuracy of MDCT in the detection of bowel and/or mesenteric injury [34–37].

For these reasons, the above-mentioned CR and US remain limited to very selected conditions to date; US, in particular, may be of some utility in the follow-up of patients with peritoneal fluid from bowel and/or mesenteric injury, initially evaluated with MDCT.

MDCT study protocol

In the era of MDCT, all exams must be performed with a high-resolution protocol, with slice thickness and a reconstruction interval values equals to 1 mm, and completed by multiplanar reconstructions [4, 14, 17, 18].

CT scans before contrast medium administration are essential in patients with suspected BIMT for several reasons:

1. free air collections from a traumatic bowel perforation and/or area of mesenteric fat characterized by abnormal attenuation caused by the traumatic event may be identified;
2. the density of any endoabdominal fluid collection and/or of the bowel walls may be easily assessed (e.g. a hemoperitoneum from recent bleeding may be easily differentiated from other lower density collections and a post-traumatic intramural hematoma may be easily assessed by comparing the hyperdensity of the pathologic loop with the normal signal of the walls of the adjacent segments) [14, 18].

A biphasic, arterial, and venous assessment after the intravenous infusion of 120–150 ml of iodinated contrast material at sufficient rate (≥3 ml/s) is recommended to detect active bleeding and identify perfusion abnormalities of the intestinal loops. According to the "whole body" CT protocol for trauma, an acquisition in the late phase, 3–5 min after starting the infusion, may be useful to rule out low-flow active bleeding [4, 14, 38, 39].

In the past decades, usefulness of oral contrast medium administration in patients with suspected bowel and/or mesenteric injury was the subject of controversy between various centers. To date, most of the evidences discourage [4, 14, 40–42] the administration of oral contrast material before the execution of the CT exam because of being time-consuming (time required for its preparation, its administration per os or using a nasoenteric probe, and its progression along the intestine may significantly affect the patient's prognosis by retarding the identification of traumatic injuries—e.g. active bleeding—requiring urgent interventions) and not diagnostically essential, especially in conditions of limited bowel distension. Moreover, the administration of oral contrast material in the emergency patients with suspected BIMT represents a potential source of pitfalls and misdiagnoses: the spread of the iodine-based, endovenous contrast medium from an intraperitoneal traumatic rupture of the bladder may mimic the spillage of the oral contrast material from intestinal loops and extraluminal oral contrast material from injured bowel loops may mimic extravasated contrast medium from ruptured vessels [4, 14, 40–43].

Features and CT classification of traumatic intestinal injuries

The effects of a trauma on the intestine depend on several factors: the type of traumatic force itself, the anatomical features of the intestinal segment on which the force acts, the degree of distension of the lumen, and the type of intestinal contents (a high content of dietary fibers is a recognized risk factor).

Traumatic injuries of the bowel can be classified, according to a prognostic criterion, into "major" and "minor" [44].

The only major intestinal injury is the "full-thickness" tear of the intestinal wall resulting in the spillage of enteric contents into the abdominal cavity: a continuity is created between the septic intraluminal ambient and the peritoneal cavity with consequent risks of chemical peritonitis. These conditions demand proper and timely interventions in the quickest time possible [12].

Minor intestinal injuries are represented by incomplete tears of the intestinal wall, intramural hematomas, and parietal contusions; such alterations of the bowel wall, although may rarely evolve into a "secondary" perforation due to focal-segmental metabolic and/or vascular disorders, are now widely managed non-operatively [45]. Both in major and minor bowel injuries from BAT, then, "specific" and "non-specific" CT-signs can be detected.

Specific signs include the direct visualization of an interruption of the bowel wall, the extravasation of enteric contents (e.g. feces, previously orally administered positive contrast medium), and the parietal hematoma.

Non-specific signs are extraluminal air collections, segmental-focal bowel wall thickening and/or abnormal enhancement, intraperitoneal fluid, and mesentery "infiltration".

Specific CT signs of traumatic intestinal injuries

Interruption of the bowel wall

Although this sign (Fig. 1) is 100 % specific [1, 4, 12, 26, 46–48], its sensitivity is low (approximately 7 %) because

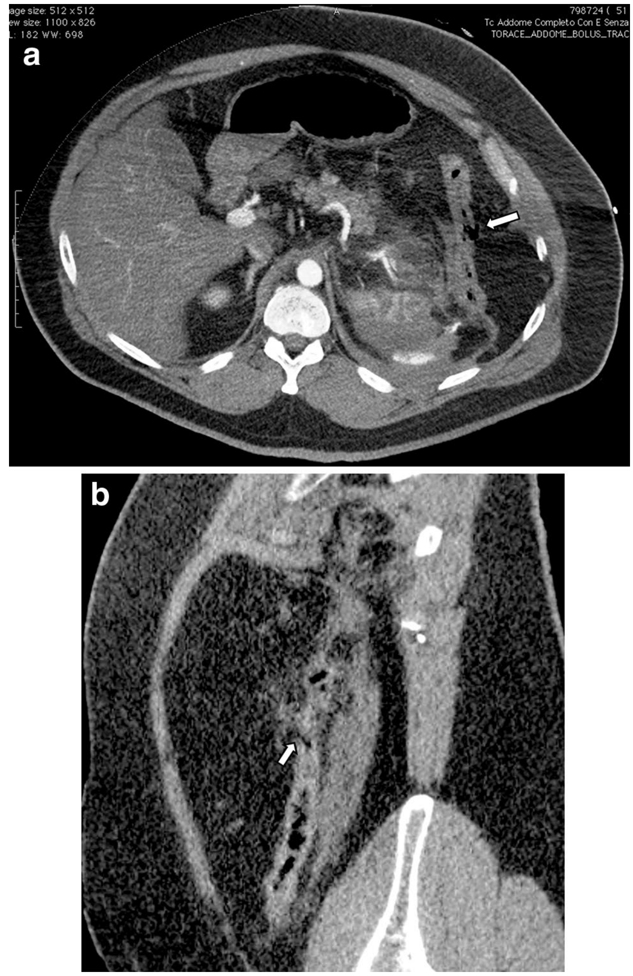

Fig. 1 Young male patient with grade III—splenic injury, diaphragmatic tear, and "stretching" lesion of the left renal artery from high energy—road traffic accident. **a** Axial MDCT scan shows a focal interruption of the parietal lining of the proximal-middle descending colon on its lateral aspect, with evidence of an air nucleus adjacent to the wall (*arrow*). Distal transverse and descending colon appears collapsed, with segmental alteration of its parietal enhancement just prior to the wall discontinuity. **b** Parasagittal MDCT reformation image confirms the focal discontinuity of the descending colon (*arrow*), also highlighting secondary mesenteric changes (stranding, "infiltration"). At surgery, extensive resection of the colon (distal transverse and descending colon, the latter extensively devitalised) was performed

in most of the cases bowel lesions are small and not of "full-thickness"; the majority of these conditions cannot be directly identified at CT but only with a meticulous surgical exploration.

Extraluminal spillage of enteric contents

Similarly to the above-described sign, extraluminal spillage of enteric contents (such as fluid, solid ingests, feces, and oral contrast material) is highly specific but affected by low-sensitivity values (12 %) [1, 4, 12, 26, 48–50] even if the study is preceded by the administration of oral contrast medium.

Intramural hematoma

Intramural hematoma represents a specific finding in BIMT, difficult to detect in most of the cases, being recognized only after a careful retrospective analysis of the cases as an abnormal parietal mass [12, 46–50].

Identification is more frequent in duodenal injuries (for its peculiar anatomical position, a direct force may crush the viscus against the spine, as frequently happens in traumas from bicycle's handlebars, typical of the childhood and the adolescence [20–22], or in traumas from steering wheel in the adult age) and rare in colonic lesions. Flexion–distraction fractures of L1–L2 (so called "Chance fracture") have been reported in association with duodenal intramural hematomas [1–3, 14, 18].

In case of duodenal involvement, bowel thickening may be observed in association with fluid in the anterior pararenal space, making it challenging to differentiate a wall hematoma from a traumatic duodenal perforation. In such cases, presence of air collections and/or bubbles in the anterior pararenal space address to the diagnosis of duodenal perforation [14]. Treatment is usually conservative: at a medium to long term, most of the hematomas resolve spontaneously within 3 weeks. In a limited percentage of cases complications are observed in the form of luminal stenosis or obstruction [46–49].

Non-specific CT signs of traumatic intestinal injuries

Extraluminal air collection (intraperitoneal, mesenteric or retroperitoneal)

Free extraluminal air represents a non-specific but highly suggestive sign of intestinal injury from BAT [26, 30, 33]. When observed even in the absence of specific CT signs (interrupted intestinal wall, extraluminal spillage of enteric contents, intramural hematoma), a bowel injury should always be sought. Coexistent ancillary signs such as bowel wall thickening, abnormalities of parietal enhancement, free peritoneal fluid, and mesenteric infiltration may strengthen the diagnostic suspicion, helping in the differential diagnosis with other causes potentially associated with the detection of free air in the abdomen as a result of the traumatic event (previous execution of a diagnostic peritoneal lavage, diffusion of air from the mediastinum, mechanical ventilation, pulmonary barotrauma, pneumothorax, chest and diaphragmatic injury, air coming from the female genital apparatus or from a laceration of the

Fig. 2 Axial CT scan shows subtle antideclivous pre-hepatic air collection (*arrow*) associated with large perihepatic and perisplenic fluid consisting with hemo-pneumo-peritoneum

intraperitoneal side of the bladder). The so-called "pseudo-pneumoperitoneum" (air entrapped between the abdominal wall and the parietal peritoneal layer) represents a potential diagnostic pitfall, mimicking true pneumoperitoneum.

Extraluminal air collection is subdivided into free floating air (pneumoperitoneum and retroperitoneum) and mottled air bubbles (air entrapped within mesenteric layers).

Free floating peritoneal air is typically localized right off of the anterior abdominal wall or along the anterior surface of the liver and spleen, being easily identifiable even in small quantities (Fig. 2).

The term "mottled air bubbles" indicates air nuclei confined within the mesenteric sheets, into the lumen of the mesenteric and portal veins, in the thickness of the intestinal wall or right off of a gas-filled hollow viscus (Fig. 3a–d); their detection is more challenging and time-consuming, justifying the limited overall sensitivity reported in the literature for free air at CT (44–55 %). Mottled air bubbles, especially if adjacent to a bowel loop, have higher positive predictive value for intestinal lesion than free floating peritoneal air. This sign may suggest the site of a bowel injury.

A traumatic perforation of the duodenum and of the dorsal sides of the ascending and descending colon may cause a pneumoretroperitoneum: extraluminal air extends through the fascial planes and may dissect them, being so detectable even at a great distance from the site of perforation.

As a general rule, in all patients with suspected hollow viscus injury from BAT, CT images should be reviewed with lung or bone window settings, in addition to the routine soft tissue ones, to assess even small amounts of free abdominal air.

Intraperitoneal fluid

In most of the cases, intraperitoneal fluid may be the only sign of a significant bowel injury at the first CT evaluation

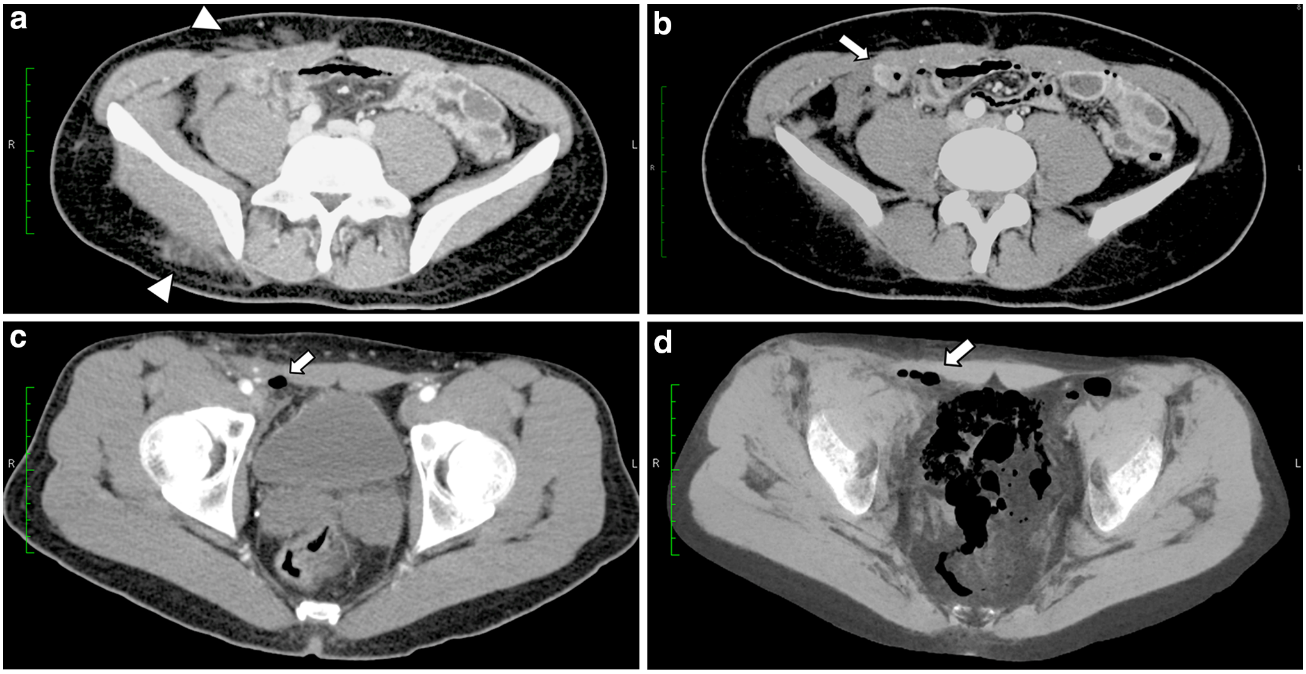

Fig. 3 CT exams of a young motorcyclist run over by a vehicle. **a** Post-traumatic soft-tissue changes of the right inferior abdominal quadrant and of the gluteal region (*arrowheads*). **b** At the same level, a tract of terminal ileum shows abnormally increased mural enhancement and parietal thickening (*arrow*), suggestive for meta-traumatic changes. **c** Axial scan and **d** MinIP axial reformation image shows small air nuclei (*arrows*) behind the posterior aspect of the ventral parietal peritoneal sheet in the right iliac fossa. The latter finding is in keeping with ileal loop traumatic perforation

[14, 29, 51]. However, pneumoperitoneum or retropneumoperitoneum may not be visible immediately after a traumatic perforation, taking some hours to appear. Therefore, management of patients with intraperitoneal fluid as the sole finding on CT scans includes 6–8 h follow-up CT examination, depending on the clinical context [29, 51, 52].

Non-physiologic amounts of free intraperitoneal fluid (>75 ml in minimally resuscitated women of child bearing age, >25 ml in minimally resuscitated adult males and >25 ml in children) without evidence for intraperitoneal solid organ injury raises the suspicion of occult hollow viscus injury [29, 51, 52].

Distribution of fluid collections may indicate potential organ injury involvement. Actually, while hemoperitoneum from laceration of the liver or spleen is classically distributed in the subphrenic spaces, along the parieto-colic gutters and in the pelvis, in case of a mesenteric or intestinal injury fluid is more frequently observed among the loops and within the mesenteric folds, forming typical polygonal-shaped collections (Fig. 4). In the case of a serosal laceration, in fact, blood spreads through the mesenteric folds with a "V-shaped" morphology, with the base corresponding to the loop and the apex to the mesenteric root. Fluid from laceration of a retroperitoneal hollow viscus tends to remain localized close to the site of injury [53].

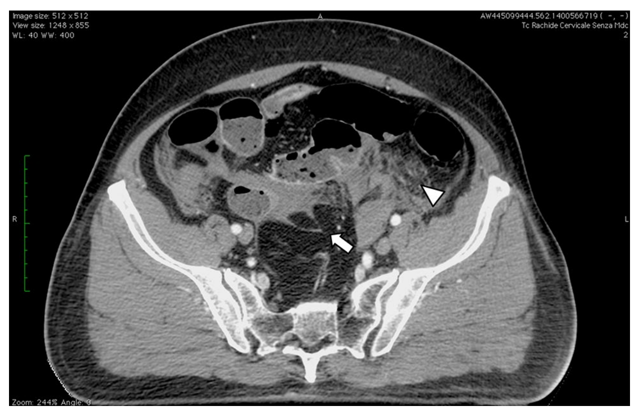

Fig. 4 Axial MDCT scan shows fluid among the loops and within the mesenteric folds, forming typical polygonal-shaped collections (*arrow*) from intestinal-mesenteric injury. Mesenteric "infiltration" is also appreciable (*arrowhead*)

Origin of a peritoneal fluid collection may be also deduced from its densitometric characteristics: a low-density collection (average densitometric values lower than 20 HU, comparable to those of the bile inside the gallbladder or of the urine in the bladder) suggests spillage of fluid from the intestine, a medium-density collection (>25 HU) in general largely consists of extravasated

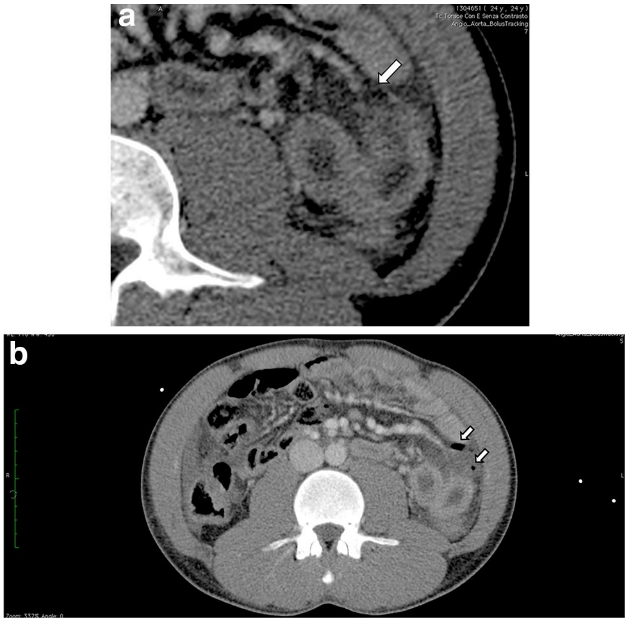

Fig. 5 **a** Abnormal parietal thickening and enhancement of two ileal loops in the lower left fossa. Small air bubbles (*arrow*) appear to cross the anterior wall of the more lateral loop, which shows focal discontinuity of the parietal outline. Peri-visceral mesenteric fat stranding is evident. **b** Air nuclei are appreciable in the axial scan in the window setting (*arrows*)

blood, and a high-density collection (>120 HU) is attributable to extravasation of contrast medium from damaged vessels or to the spillage of oral contrast material through bowel wall full-thickness tears [14, 54]. Notwithstanding these general assumptions, densitometric values do not assume an absolute diagnostic value: a blood collection, for example, can appear with reduced density because of decreased hematocrit or the admixture of the blood with other fluids of lesser density (e.g. ascites, bile, urine).

Bowel wall thickening

A disproportionate segmental-focal circumferential thickening of the walls of a loop or a bowel wall thickness >3 mm is considered a non-specific but significantly more sensitive sign of bowel traumatic injury compared to free air and extravasated enteric contents, being appreciable in approximately 75 % of full-thickness lacerations [14, 26]. If intramural air is appreciable at the same level at CT images, specificity of bowel wall thickening as a sign of intestinal injury from BAT increases [14, 30, 33], suggesting also the possibility of a full-thickness laceration (Fig. 5). A non-circumferential parietal thickening, limited to the declivous side of the loop should not be interpreted as a sign of intestinal traumatic injury, being only apparent, caused by the stratification of the intestinal contents [55].

"Shock bowel" represents a transient condition source of false positivity for post-traumatic bowel wall thickening in patients with BAT: diffuse parietal thickening, fluid distension of the loops, and increased bowel wall enhancement may be secondary to deep hypotension with hypoperfusion complex. Vascular permeability increases with a preferential shift of blood flow to the mucosa probably during hypoperfusion . Identification of the hypoperfusion complex (flat inferior vena cava, increased enhancement of the adrenal glands, bowel, pancreatic and retroperitoneal edema, "nutmeg liver" appearance, or periportal oedema (concentric halo of low attenuation around the portal veins) may help in the differential diagnosis between "shock bowel" and segmental/focal bowel wall thickening from bowel injury [56].

A reversible, diffuse bowel wall thickening may also be associated with iperhydration and volume overload; edematous imbibitions of the mesentery and fluid film in the periportal and pericholecystic spaces are often observed while the increased wall enhancement and the signs of systemic hypotension are absent [55].

Further possible sources of false-positivity for bowel wall thickening from trauma are the lack of bowel distension, coexisting inflammatory-infectious diseases, isolated tear of the mesentery, interruption of the vascular arterial supply or venous drainage, and non-traumatic hematoma.

Abnormal bowel wall enhancement

An abnormal (decreased or increased) (Fig. 3b) enhancement of the walls of an intestinal loop segment is highly suggestive of a traumatic intestinal injury [14, 18], especially if associated with a polygonal fluid collection in the adjacent mesentery or with free fluid in the peritoneal cavity.

Bowel wall density may be evaluated in relation to that of the psoas muscle or of the contiguous vessels. Patchy, irregular areas of increased impregnation of contrast medium represent a non-specific sign of full-thickness laceration. Conversely, areas of decreased or absent bowel wall enhancement indicate traumatic bowel ischemia due to mesenteric vascular laceration. The latter condition will be treated in greater detail in the following paragraphs.

Hypoperfusion can paradoxically manifest itself as increased wall enhancement in the early stages due to the passage of molecules of contrast medium through the more permeable damaged vascular endothelium [56].

Acute intestinal behaviors

Variations in tone, motility, shape, and location of the intestinal loops may represent the first hint of a small bowel or colonic traumatic injury even in the absence of small amounts of free fluid and air [24].

In most of the cases, reflex spastic ileus (RSI) due to persistent contracture of bowel with a complete absence of intestinal gas is the first sign in order of appearance. When hypertonic spastic reaction ends, the bowel loops relax and the tone decreases leading to reflex hypotonic ileus (RHI) [24].

RSI and RHI are characterized by an "intrinsic evolutivity" and should not be considered as separate entities, with the transition of each of these in the other at any time in response to internal or external stimuli [24] being possible.

Features and CT classification of traumatic mesenteric injuries

Mesenteric injuries include a broad spectrum of traumatic findings from simple contusion to mesenteric avulsion.

In the majority of the cases traumatic lesions of the mesentery are isolated, rarely associated with lesions of the intestine and parenchymal organs [31, 57]. Similarly to traumatic bowel injuries, mesenteric injuries are distinguished, based on a surgical and prognostic criterion, in "major" and "minor" [31].

"Major" mesenteric injuries, essentially represented by active blood extravasation, avulsion of the meso resulting in intestinal ischemia and full-thickness tear of the meso, require urgent operative treatment.

"Minor" lesions include partial lacerations of the meso, focal mesenteric contusions, and the stable mesenteric hematomas; these conditions are treated conservatively, with a careful clinical and instrumental observation.

Also for mesenteric traumatic injuries specific and non-specific CT signs are described [14, 18, 30]. Specific CT injuries are essentially represented by avulsion of a meso resulting in ischemic changes of the loop, active bleeding, and mesenteric hematoma, while non-specific CT signs include mesenteric infiltration and fluid collections.

Specific CT signs of traumatic mesenteric injuries

Avulsion of the meso with intestinal ischemia

An injury to the meso in correspondence to its insertion on the intestinal loop, manifesting at CT as a triangular-shaped fluid collection, with the base corresponding to the loop and the apex facing towards the mesenteric root, may compromise the vascular supply of the loop. Therefore, in this condition, mesenteric anomalies at CT are associated with signs of intestinal ischemia, varying depending on the severity of the injury, the vessel involved (arterial, venous or "combined" injury) and the mechanisms of compensation [33]. A loop deprived of its blood supply is at risk of "secondary" perforation, with appearance of the classic CT findings of perforation several hours after the traumatic insult [35].

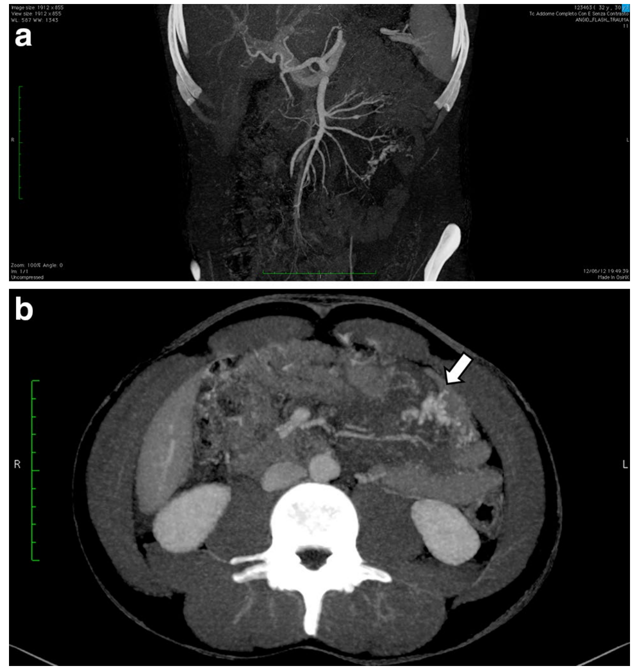

Fig. 6 **a** Coronal MIP reformation (late arterial phase) showing active blood extravasation from a vessel of the arterial mesenteric tree. **b** Axial MIP reformation in the same patient better depicts the refurnished hematoma within the meso (*arrow*)

Active blood extravasation

A mesenteric tear with an associated vascular injury can cause hemorrhage (resulting in hemoperitoneum or, more rarely, hemoretroperitoneum) and necrosis of a bowel loop, deprived of its normal blood supply.

CT images in patients with active blood extravasation from mesenteric traumatic injury reveal a "blush" within perivisceral soft tissues characterized by densitometric values similar to those of contrast medium inside the arterial vessels; the markedly hyperdense blush is usually surrounded by a weakly and spontaneously hyperdense fluid collection, represented by the hematoma (Figs. 6, 7, 8). This sign, highly indicative of "major" mesenteric injury

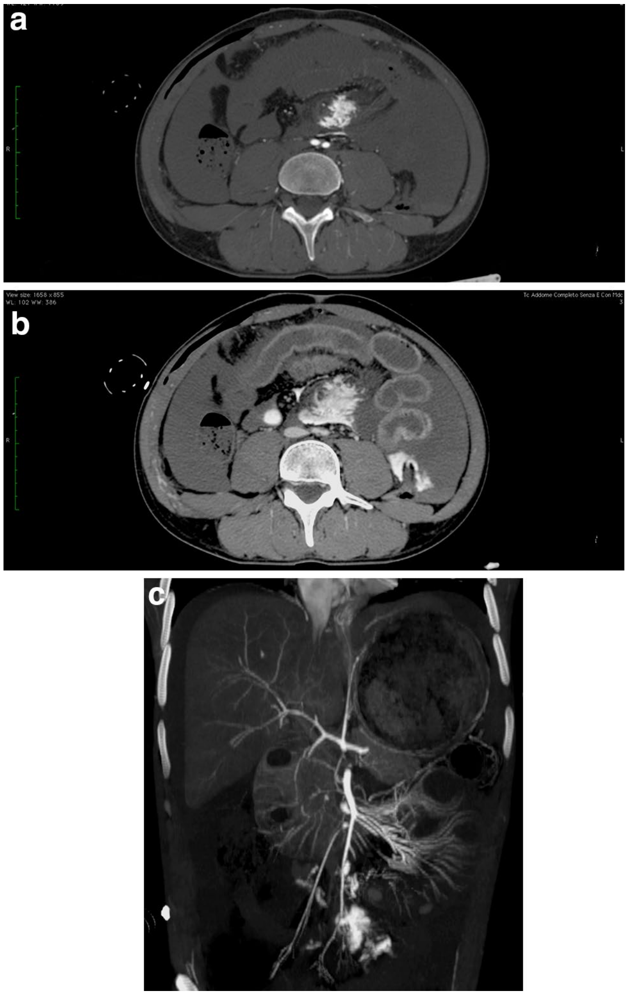

Fig. 7 Arterial active blood extravasation from intestinal-mesenteric traumatic injury. Axial scans in the arterial (**a**) and venous (**b**) phases of the exam show conspicuous increase in the amount of the extravasated contrast medium in the time interval between the two phases. MIP coronal image depicts the contrast medium blush from the mesenteric arterial tree (**c**)

(specificity rates of 100 %) [54], suggests the need for an urgent operative treatment.

In cases of mesenteric traumatic injury resulting in active extravasation, significant traumatic forces are generally involved. For this reason potential "major" lesions of the adjacent loops should be carefully excluded [54].

Mesenteric hematoma

As written, traumatic tears of the walls of mesenteric vessels are associated with the appearance of a mesenteric hematoma, whose management varies significantly depending on its degree of stability (we define "stable" a not-refurnished, "contained" hematoma, without signs of active bleeding in the vicinity). Surgery should also be considered for large, stable hematomas, potential causes

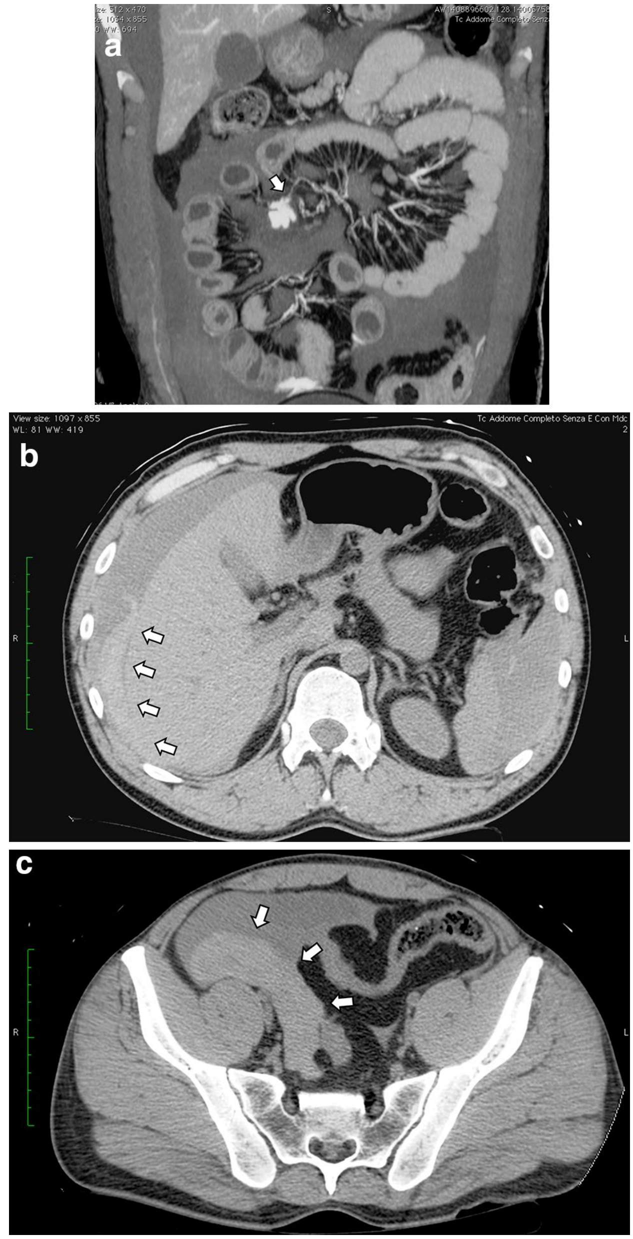

Fig. 8 Active blood extravasation from a vessel of the mesenteric arterial tree. **a** MIP coronal image displaying the source of the bleeding (*arrow*). **b**, **c** Axial scans acquired in the venous phase showing a considerable spread of the extravasated contrast medium in the perihepatic and pelvic spaces (*arrows*)

of compression of the adjacent vessels with consequent ischemic sufferance of the loops [38, 44, 47].

Density values of a hematoma will vary depending on the degree of degradation of its blood components (Fig. 9); as a general rule, the density of a hematoma is closer to that of the soft tissues than that of fluids.

Identification of a circumscribed fluid collection characterized by inhomogeneous, predominantly high density (hyperdensity at basal scans), localized in correspondence

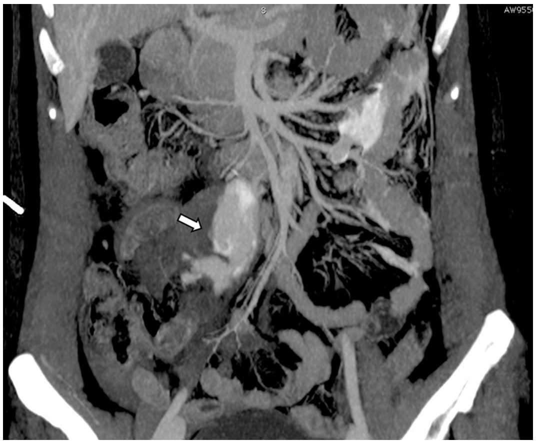

Fig. 9 Large, "refurnished" mesenteric hematoma (*arrow*): areas of different density are appreciable in the arterial phase of study, with prevalent areas of moderate hyperdensity (processed blood from recent bleeding) and several clots of marked hyperdensity corresponding to ongoing extravasation

to the bleeding site, represents the so-called "sentinel clot sign" [14, 18].

Non-specific CT signs of traumatic mesenteric injuries

Mesenteric "infiltration"

An inhomogeneous, slight increase of the density of the mesenteric fat, most of the times in the form of hyperdense striae of fat thickening, corresponds to microhemorrhagic foci (Fig. 10). This sign is poorly specific [31, 57], being generally associated with additional CT signs of "major" or "minor" mesenteric injuries or for bowel isolated lesions. When associated with a focal-segmental thickening of the intestinal wall, this densitometric alteration of the mesentery is suggestive of ischemic sufferance of the intestine due to injury of the afferent or efferent vessels.

Free abdominal fluid

Free abdominal fluid represents the non-specific sign most frequently associated with BIMT. As described before, this finding is low-specific, being potentially associated with lesions of other structures (e.g. parenchymatous organs) or coexistent physio-pathologic conditions. In the absence of traumatic injuries of abdominal parenchymatous organs, as a general rule, detection of free abdominal fluid, especially if hyperdense, a BIMT should always be excluded through the search of possible associated signs.

Analogous to what described for intestinal lesions, abdominal fluid from a mesenteric traumatic injury

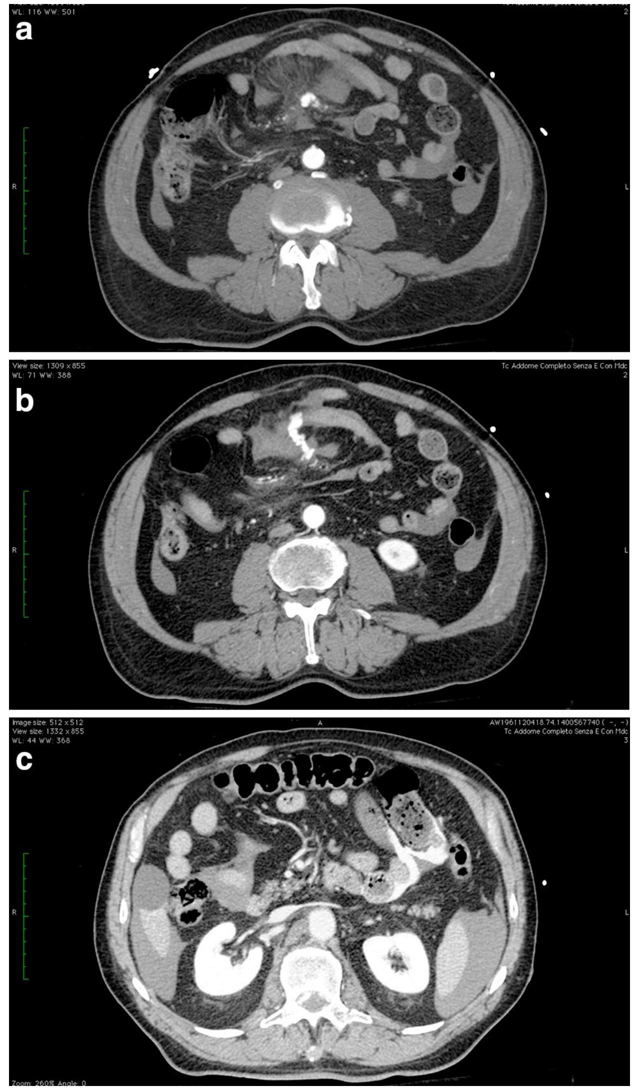

Fig. 10 **a** Axial scan showing mesenteric contusion and "infiltration", with a roundish focus of active arterial blood extravasation, better defined quantitatively in the subsequent scan. **b** Striae of hyperdensity within the meso correspond to microhemorrhagic foci. **c** A later, venous acquisition highlights the spread of the extravasated contrast medium among the loops

usually assumes a peculiar distribution, between the intestinal loops and/or within the mesenteric sheets, forming polygonal-shaped collections. In the case of injury of the serosal surface of the loop, a typical "V-shaped" triangular collection appears, with the base corresponding to the base of the loop itself and the apex directed towards the mesenteric root. As already written, the density of this collection at basal scans may indicate its nature and provenance.

Retroperitoneal fluid collections tend to remain confined for a longer time at CT controls compared to peritoneal collections [53].

Conclusions

Clinical assessment alone of patients with suspected intestinal and/or mesenteric injury from BAT is associated with unacceptable diagnostic delays. Prompt identification and proper classification of BIMT represent crucial issues in the management of patients with BAT. Prognosis of such conditions is significantly influenced by a timely diagnosis in the cases requiring immediate surgical interventions.

Although MDCT is by far not an ideal tool for investigation for several reasons (e.g. scarce CT findings in the early stages of BIMT), actually it is the best imaging we can do in the emergency setting, providing a rapid and comprehensive evaluation of BMTI.

The radiologist is asked not only to identify the signs of trauma but also to provide an indication of the clinical significance of the detected injuries, suggesting the chance of conservative treatment in the cases of mild and moderate, non-complicated or self-limiting injuries and focusing on life-threatening conditions which may benefit from immediate surgery or intervention.

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