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# The trauma concept: the role of MDCT in the diagnosis and management of visceral injuries

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**Abstract** The imaging concept in the acute trauma victim includes abdominal ultrasonography during initial triage, and contrast-enhanced computed tomography (CT) for further assessment of visceral organ injuries and active bleeding sites if haemodynamic stability can be established during initial resuscitation. Integration of modern multidector CT (MDCT) scanners in the emergency admission area greatly facilitates initial assessment of the extent of injuries in all body regions, and is therefore the emerging standard in all major centres involved in acute trauma care. Initial assessment of visceral injuries by means of CT not only allows determining the presence and extent of organ injuries and detecting active bleeding sources that may require transarterial embolisation for haemostasis, but also serves as a baseline for monitoring of conservative treatment. Specific indications for CT monitoring of conservative treatment exist in each individual organ. This concept enables the vast majority of blunt injuries of the parenchymal abdominal organs in the haemodynamically stable trauma victim to be managed without surgery.

**Keywords** Computed tomography · Abdominal trauma · Visceral injuries

## Introduction

In Europe, blunt trauma resulting from deceleration is among the leading causes of death in younger adults. Although severe injuries of the head or thoracic aorta may lead to death at the site of the accident, victims of blunt abdominal trauma often survive long enough to receive emergency treatment. Time is one of the most important factors in the early management of trauma victims, who often have injuries involving multiple organ systems. Ultrasonography, in the hands of an experienced operator, is a quick, non-invasive and readily available method for initial assessment of the acute trauma victim, and allows detection of free intraperitoneal or intrapleural fluid with very high accuracy. Nonetheless, results regarding the detection of injuries to the visceral organs have been less consistent. Because even significant organ injuries may not be associated with free intraperitoneal fluid in 25% of cases, exclusion of free intraperitoneal fluid by means of US alone must be considered insufficient to exclude visceral injuries reliably.

The increasing role of contrast-enhanced computed tomography (CT) in the management of the acute trauma victim may be explained by its ability to examine all body regions during a single examination with consistent quality. The increasing use of multidetector CT (MDCT) in the acute trauma victim has not only improved the ability to detect visceral injuries and to identify active bleeding sources by means of contrast extravasation but has also influenced the understanding of the spontaneous course of injuries that can be treated conservatively in the situation of haemodynamic stability. Although therapeutic decisions cannot be based on radiological findings alone, the information provided by CT at admission and during conservative treatment may greatly facilitate patient management [1–3].

Injury severity scores, like the organ injury scaling system (OIS) of the American Association for the Surgery of Trauma, have been proposed to facilitate clinical research [4–6]. Since a variety of criteria can be assessed on the basis of CT, radiologists involved in trauma care should be familiar with the principles of grading injuries to the different visceral organs.

## Technical aspects

Today, the emerging standard for centres involved in trauma care is integration of modern MDCT scanners in the emergency admission area. The time required for image acquisition has thus become secondary as compared to the time required for patient transfer, positioning and installation of adequate monitoring during the examination. The acquisition speed and artefact suppression algorithms as implemented in MDCT scanners have greatly improved the overall diagnostic quality of images in the acute trauma victim. CT scanning is readily performed while continuing resuscitation; and since MDCT has been implemented in the emergency admission area of our hospital, even suspected acute intra-abdominal haemorrhage is no longer considered as a general contraindication for the use of CT in the workup of polytrauma.

Although a standard CT protocol is important in the setting of trauma, the examination needs to be tailored to the patient's condition. The majority of acute trauma patients is now examined without oral contrast administration. Only in selected cases, and if the patient's condition permits, 250–500 ml of water-soluble oral contrast material (2–5%) are administered via the nasogastric tube in the emergency department and an additional 250 ml in the CT suite immediately before scanning. Additional administration of rectal contrast material is an option in patients with pelvic trauma or a suspected colon injury. Scanning parameters may vary according to different types of equipment. With our current 16-slice scanners, we typically use a collimation of 16 x 1.5 mm, pitch 1.35 with a reconstruction interval of 3/3 mm. Preliminary scanning before administration of intravenous contrast material may sometimes facilitate image interpretation but is not recommended routinely as it also increases the radiation dose significantly. An automated uniphasic bolus injection of 130–180 ml of intravenous non-ionic iodinated contrast material (60–75%) is given at 2–4 ml/s. A standard scan delay of 70–90 s may be used, but a longer delay may be preferable in patients with significant arterial hypotension in order to avoid artefacts in the early parenchymal phase or to miss extravasation of contrast material. Repeat, delayed scanning may be necessary for better demonstration of the distribution of extravasated contrast material from the blood vessels, parenchymal organs, gastrointestinal tract or urinary system. All images should be viewed immediately by the radiologist at the workstation with appropriate window settings. Depending on the questions that need to be answered, additional acquisitions may then be performed and two- or three-dimensional reconstructions can be obtained if necessary.

## Splenic injuries

Splenic injuries are commonly encountered in severe blunt abdominal trauma. It is now established that splenic injuries can be managed conservatively in approximately 70% of adults and in over 90% of children, and that transarterial embolisation may be used in actively bleeding lesions under certain clinical circumstances. Surgical intervention with splenectomy is usually reserved for severe parenchymal destruction and injuries to the hilar vessels (corresponding to OIS grade 4–5).

The important role of CT for the detection, characterisation, and follow-up of blunt splenic injuriesis is now well established, and it has become recognized that a variety of findings warrant either transarterial embolisation or surgical repair even if destruction of the splenic parenchyma is only moderate. These include active contrast extravasation from the splenic parenchyma, vascular injuries such as arteriovenous fistula, rupture of hilar vessels and an intraparenchymal contrast blush which may lead to a pseudo-aneurysm (Fig. 1). Nonetheless, predicting the outcome of conservative treatment based on morphological CT criteria at the time of admission has remained a challenge. Several investigators have proposed a variety of CT-based grading systems similar to the surgical organ injury scale (OIS) or scores that were based on the extent of capsular or parenchymal laceration and haematoma as well as the degree of haemoperitoneum at the time of admission. So far, none of these systems has been found sufficiently reliable to distinguish those trauma victims who are at risk of developing delayed splenic rupture from those who are not [7–9].

Particular diagnostic pitfalls exist in the context of trauma. In the hypotensive trauma victim, parenchymal enhancement is often delayed and heterogenous and may thus prevent detection or even simulate an injury as late as 70 s after contrast injection. Repeat scanning may become necessary in such a situation.

## Liver injuries

The widespread use of CT over the past decades has shown that most liver injuries heal spontaneously, even when involving more than two segments. Unlike in splenic injuries, secondary rupture of hepatic injuries is exceedingly rare. CT is well suited to delineate the presence, extent and location of blunt injuries of the hepatic


**Fig. 1a,b** Blunt abdominal trauma. **a** Admission axial CT image shows a grade-4 splenic laceration (*asterisk*), without evidence of vascular lesion. **b** Control CT, performed 4 days after trauma, reveals a focal blush of contrast, in the periphery of the spleen (*arrow*), corresponding with a pseudo-aneurysm, requering intra-arterial embolisation


**Fig. 2** Blunt abdominal trauma. Coronal reconstruction showing large diaphragmatic hernia *H* following diaphragmatic rupture (*arrows*)

parenchyma and to demonstrate active intra- or extrahepatic bleeding. Transarterial embolisation is recommended for treatment of active haemorrage. Various patterns of injuries include capsular tear, intraparenchymal laceration or fracture, subcapsular or intraparenchymal haematoma and partial devascularisation due to parenchymal contusion**.** In most patients with blunt liver trauma in whom helical CT shows no active haemorrhage, who are haemodynamically stable, and who do not require laparotomy because of extrahepatic injuries, even extensive parenchymal damage due to blunt liver trauma is now usually managed conservatively [10]. Disruption of the portal triad may result in the formation of a false aneurysm or a posttraumatic arterio-portal fistula within a week after the traumatic event. These lesions can be readily demonstrated by CT and can then be treated definitively by transcatheter embolisation. Other complications observed during conservative treatment of blunt hepatic injuries include biloma formation due to bile duct leakage, superinfection and abscess formation. Follow-up CT is thus warranted for monitoring of conservative treatment of major hepatic injuries in order to enable early detection and adequate treatment of such complications.

## Gastro-intestinal and diaphragmatic injuries

CT signs of gastro-intestinal injuries are often subtle and their detection requires images of optimal resolution and thorough inspection. Direct signs indicating full-thickness bowel perforation include discontinuity of the gastro-intestinal wall and spillage of contrast material or luminal contents into the peritoneal cavity or retroperitoneum, and free extraluminal, extra- or intraperitoneal air. A second group of indirect CT signs are a sentinel clot adjacent to a loop of bowel, visualisation of contrast extravasation originating from a mesenteric vessel, focal thickening of the wall of the small bowel (> 3 cm) and intramesenteric fluid or haematoma, and a streaky ap-

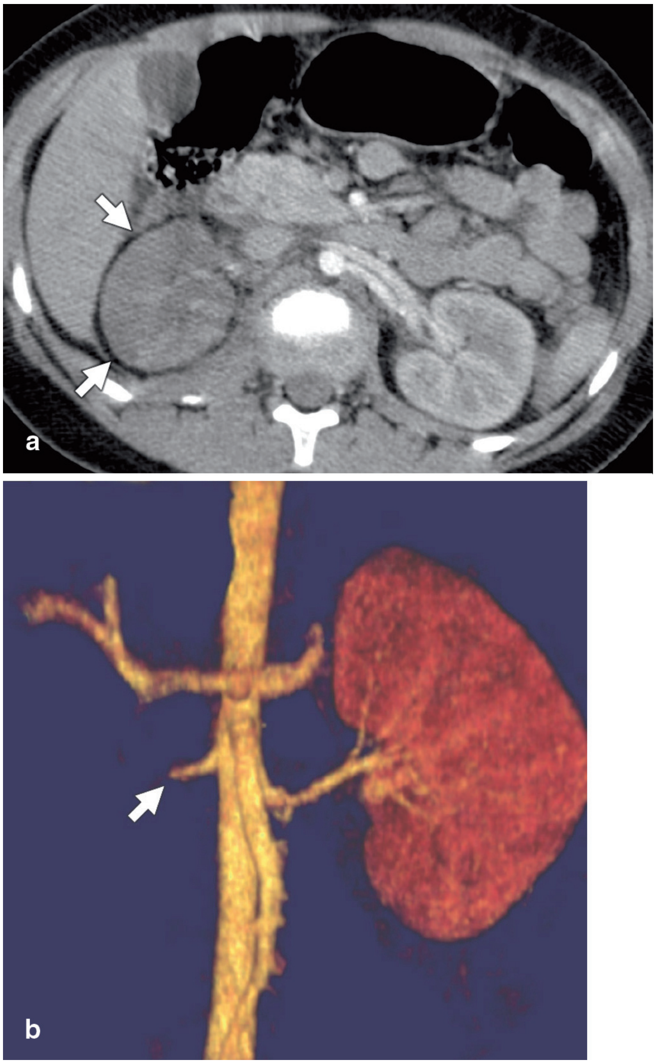

**Fig. 3a,b** CT obtained 3 h after blunt abdominal trauma (skiing accident). **a** Axial CT image shows a non-enhancing right kidney (*arrows*). **b** 3-D reconstruction shows tapering of the right renal artery with complete occlusion 1.5 cm from its origin (*arrow*). Surgical revascularisation allowed partial functional recovery

pearance of the mesenteric fat**.** Mesenteric vascular injury may lead to bowel necrosis due to ischemia, which may become visible due to intramural gas collections only hours or even days after the initial traumatic event. The reported overall sensitivity of CT for the detection of blunt gastrointestinal tract injuries is as high as 85–95% [3, 11–15].

Early diagnosis of diaphragmatic rupture is essential in order to avoid complications due to intrathoracic herniation or even strangulation of gastro-intestinal organs. When using routine transverse sections, rupture of the diaphragmatic dome, which usually occurs on the left side, may be missed in one-third of cases unless 2-D sagittal or coronal reformatting is used [16, 17] (Fig. 2).

## Renal injuries

Renal injuries are commonly encountered after blunt abdominal trauma. Retroperitoneal haemorrhage is often self-limited due to spontaneous tamponade by the retroperitoneal fasciae. Approximately 80% of renal injuries may be considered minor and heal spontaneously. Common CT findings in such injuries include lesions such as contusions seen as ill-defined perfusion defects, superficial lacerations, segmental renal ischemic infarcts (seen as segmental perfusion defects) and subcapsular or perirenal hematoma.

The evaluation of blunt renal trauma requires information about the renal hilar vessels as well as morphological and functional information about the renal parenchyma [18–20]. Multiplanar and 3-D reconstructions are highly recommendable for optimal display of the relationship of the parenchyma, the hilar vessels and the proximal collecting system, or to display the extent of arterial injury (Fig. 3). During the standard early parenchymal phase, renal enhancement is quite inhomogeneous due to intense corticomedullary differentiation. A second helical acquisition after a 3-min delay may provide valuable additional information regarding the renal collecting system, the ureters and the urinary bladder, and may also help distinguish between contrast extravasation from the renal pelvis (posttraumatic urinoma) and active haemorrhage. In patients undergoing conservative treatment of renal injuries, follow-up with CT may be recommended under certain conditions. These include large retroperitoneal haematoma, large urinoma, major devascularised or shattered segments and transarterial embolisation treatment of vascular lesions such as pseudo-aneurysm or arterio-venous fistula [3]. CT–follow up is also indicated whenever there is a suspicion of a pre-existing cystic or solid renal mass.

## References


1. Linsenmaier U, Krotz M, Hauser H, t al. (2002) Whole-body computed tomography in polytrauma: techniques and management. Eur Radiol 12:1728–1740
2. Becker CD, Mentha G, Terrier F (1998) Blunt abdominal trauma in adults: role of CT in the diagnosis and management of visceral injuries Part 1: liver and spleen. Eur Radiol 8:553–562
3. Becker CD, Mentha G, Schmidlin F, Terrier F (1998) Blunt abdominal trauma in adults: role of CT in the diagnosis and management of visceral injuries Part 2: gastrointestinal tract and retroperitoneal organs. Eur Radiol 8: 772–780
4. Moore EE, Shackford SR, Pachter HL, et al. (1989) Organ injury scaling: spleen, liver, and kidney. J Trauma 29:1664–1666
5. Moore EE, Cogbill TH, Malangoni MA, Jurkovich GJ, Champion HR, Gennarelli TA, Mc Aninch JW, Pachter HL, Shackford SR, Trafton PG (1990) Organ injury scaling II: pancreas, duodenum, small bowel, colon, rectum. J Trauma 30:1427–1429
6. Moore EE, Cogbill TH, Jurkovich GJ, Shackford SR, Malangoni MA, Champion HR (1995) Organ injury scaling: spleen and liver (1994 Revision). J Trauma 38:323–324
7. Becker CD, Spring P, Glättli A, Schweizer W (1994) Blunt splenic trauma in adults: can CT findings be used to determine the need for surgery? AJR 162:343–347
8. Gavant ML, Schurr M, Flick P, Croce MA, Fabian T, Gold R (1997) Predicting clinical outcome of nonsurgical management of blunt splenic injury: using CT to reveal abnormalities of splenic vasculature. AJR 168:207–212
9. Federle MP, Courcoulas AP, Powell M, Ferris JV, Peitzman AB (1998) Blunt splenic injury in adults: clinical and CT criteria for management, with emphasis on active extravasation. Radiology 206:137–142
10. Becker CD, Gal I, Baer HU, Vock P (1996) Blunt hepatic trauma in adults: correlation of CT injury grading with outcome. Radiology 201:215–222
11. Sherck J, Shatney C, Sensaki K, Selivanov V (1994) The accuracy of computed tomography in the diagnosis of blunt small-bowel perforation Am J Surg 168:670–675
12. Holmes JF, OffermanSR, Chang CH, et al. (2004) Performance of helical computed tomography without oral contrast for the detection of gastrointestinal injuries. Ann Emergency Med 43:120–128
13. Hagiwara A, Yukioka T, Satou M, Yoshii H, Yamamoto S, Matsuda H, Shimazaki S (1995) Early diagnosis of small intestine rupture from blunt abdominal trauma using computed tomography: significance of the streaky density within the mesentery. J Trauma 38:630–633
14. Casey LR, Vu D, Cohen AJ (1995) Small bowel rupture after blunt trauma: CT signs and their sensitivity. Emergency Radiol 2:90–95
15. Dowe MF, Shanmuganathan K, Mirvis SE, Steiner RC, Cooper C (1997) CT findings of mesenteric injury after blunt trauma: implications for surgical intervention. AJR 168:425–428
16. Murray JG, Caoili E, Gruden JF, Evans SJJ, Halvorsen RA, Mackersie RC (1996) Acute rupture of the diaphragm due to blunt trauma: diagnostic sensitivity and specificity of spiral CT. AJR 166:1035–1039
17. Israel RS, Mayberry JC, Primack SL (1996) Diaphragmatic rupture: use of helical CT scanning with multiplanar reformations. AJR 167:1201–1203
18. Miller KS, McAninch JW (1995) Radiographic assessment of renal trauma: our 15-year experience. J Urol 154:352–355
19. Nunez DB, Becerra JL, Fuentes D (1996) Traumatic occlusion of the renal artery: helical CT diagnosis. AJR 167:777–778
20. Poletti PA, Wintermark M, Schnyder P, Becker CD (2002) Traumatic injuries: role of imaging in the management of the polytrauma vietim (conservative expeetation). Eur Radiol 12:969–978