Tutorial 4: Body Trauma

Gerard M. Healy and Colin P. Cantwell

Aims and Guidance for Tutors

Radiology plays a vital role in the management of patients with thoracic and abdominal trauma. The objective of this tutorial is to familiarise medical students with the basic principles of body trauma imaging and the common patterns of injury. The therapeutic role of Interventional Radiology is briefly reviewed.

Introduction

- Radiology plays an important role in the assessment and management of patients who have suffered major trauma. The goal is rapid identification of life threatening conditions such as pneumothorax, haemothorax, aortic injury or laceration of an intraabdominal solid organ.
- Trauma can be divided into blunt (approx. 80% of total cases) or penetrating. This chapter focuses upon blunt trauma.
- The Advanced trauma life support (ATLS) program from the American College of Surgeons defines two stages of assessment in trauma; the primary survey and later the secondary survey.

G. M. Healy (✉) · C. P. Cantwell
Department of Radiology, St. Vincent's University Hospital, Dublin, Ireland
e-mail: ger.healy@svuh.ie

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Radiological Modalities Utilised

Plain radiography (X-ray)

- Rapid and non-invasive. Can be performed in the Emergency Department (ED) resuscitation room as an adjunct to the primary survey.
- Exposes the patient to low dose of ionizing radiation.
- A standard 'trauma series' performed in the emergency department includes anterior-posterior (AP) and lateral radiographs of the cervical spine, AP chest and AP pelvis.
- Haemodynamically unstable patients will usually go directly to advanced imaging (CT) without plain radiography.

Ultrasound

- A portable ultrasound (US) machine can be used at the time of primary survey in the trauma area to see if the patient has cardiac haemopericardium or free fluid with the abdominal or pleural space (may be due to bleeding or bowel perforation) using gel and an ultrasound probe on the skin. This is called a Focused Assessment with Sonography for Trauma (FAST) scan.
- Does not expose the patient to ionizing radiation.
- The results of an US scan are limited by operator skill and patient factors such as bowel gas and obesity.
- Good at detecting free abdominal fluid, but cannot outrule bleeding or organ damage.

Computed tomography (CT)

- CT is the standard of care for imaging of the major trauma patient. A whole body CT (from top of head to mid-thigh) is recommended by the National Institute for Health and Care Excellence (NICE) for all adults with major blunt trauma, where multiples injuries are suspected.
- ATLS considered CT to be an adjunct to the secondary survey.
- Rapid and non-invasive.
- Generally not portable (except in very specialist centres).
- Exposes patient to moderate dose of ionizing radiation.
- Multiplanar reconstruction (axial, coronal and sagittal) improves accuracy of reporting.
- Intravenous contrast should be administered to improve sensitivity of the test for solid organ injury and vessel injury. Typically, a chest trauma CT is

acquired in non-contrast and then arterial phase contrast to assess for aortic injury, while an abdomen trauma CT is acquired in the venous phase, to assess for solid organ injury. Another option is a split bolus technique, which provides a porto-venous and arterial phase CT abdomen simultaneously.
- Multiphasic imaging may be performed if active haemorrhage is suspected. This may include all or some of the following phases: non-contrast, arterial, portal venous. A 5–10 min delayed urographic phase can be performed if urinary tract injury is suspected clinically.

Interventional radiology (IR)

- Uses ultrasound and fluoroscopy (real time radiography) to guide minimally invasive treatments to stop bleeding.
- IR can manage major haemorrhage, by blocking the bleeding artery (embolization) or by using a covered metal stent to control the ruptured vessel.

Image Interpretation

- Following a structured approach to image interpretation in emergencies is advised by international guidelines, such as from the Royal college of Radiologists (see 'Further reading').
- Trauma centres will often have proformas for the primary imaging survey of severely injured patients, using which any life-threatening diagnosis can be rapidly and clearly communicated to the trauma team leader.

Radiologist's tips

- CT is the imaging procedure of choice in evaluating the major trauma patient.
- Initial assessment should focus upon identification and prompt communication of life-threatening conditions to the trauma team leader. Reporting should adhere to the ATLS protocol (primary survey, secondary survey).

Review of Relevant Radiological Anatomy

See Figs. 1 and 2.

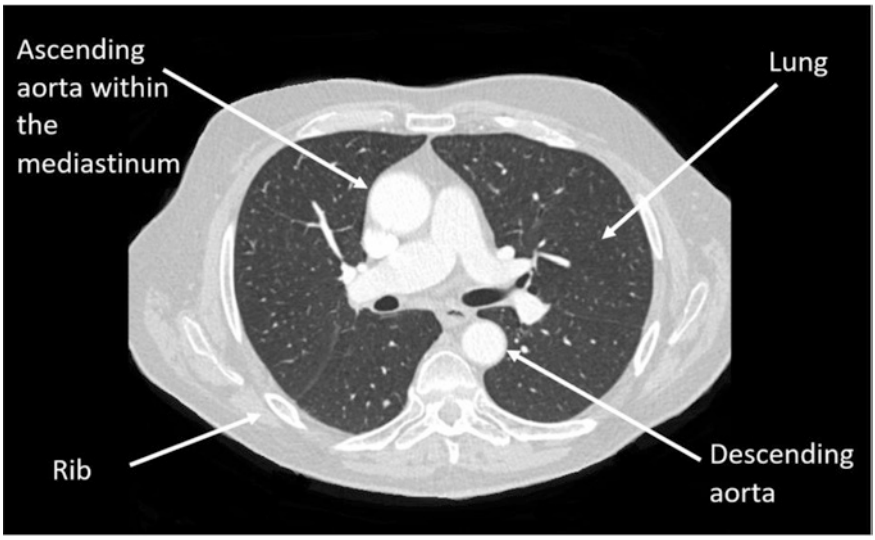

Fig. 1 Axial contrast-enhanced CT of the chest presented in lung windows

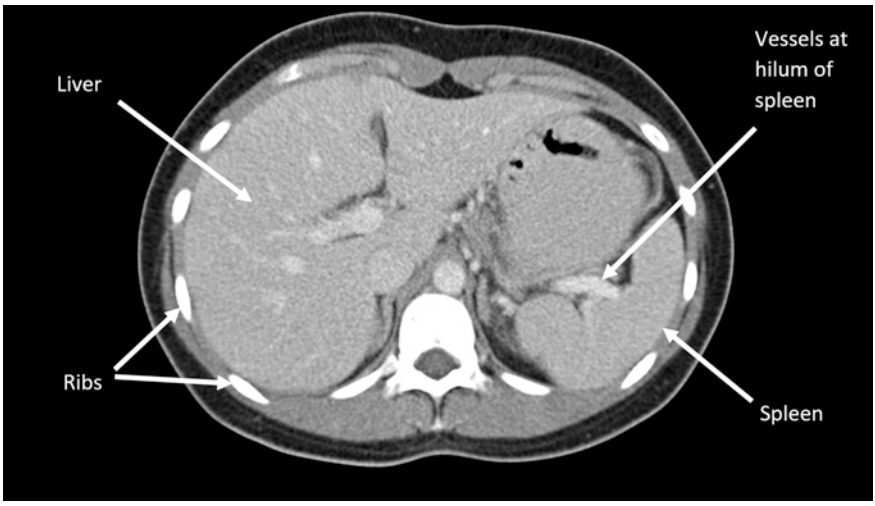

Fig. 2 Axial contrast-enhanced CT of the abdomen presented in soft tissue windows at the level of the splenic and hepatic hila

Common Patterns of Trauma: Chest

Pneumothorax

- Air within the pleural cavity. This may be caused by an injury to the lung parenchyma, airways or chest wall. The lung then collapses reducing the capacity of the respiratory system to oxygenate blood.
- In some cases a pneumothorax can enlarge and become pressurized called a tension pneumothorax. This will push the mediastinal structures including the heart and other lung away, compromising blood flow. This condition can be rapidly fatal if not identified and corrected with a chest drain.
- A large or tension pneumothorax is usually clinically apparent during the primary survey and can be treated with chest drain insertion without the need for imaging.

Pneumothorax: Key imaging features

- Identification of the edge of the lung separate from the chest wall (Fig. 3).
- The deep sulcus sign occurs in patients who are X-rayed supine and it appears as a unilateral 'deep' costophrenic sulcus.

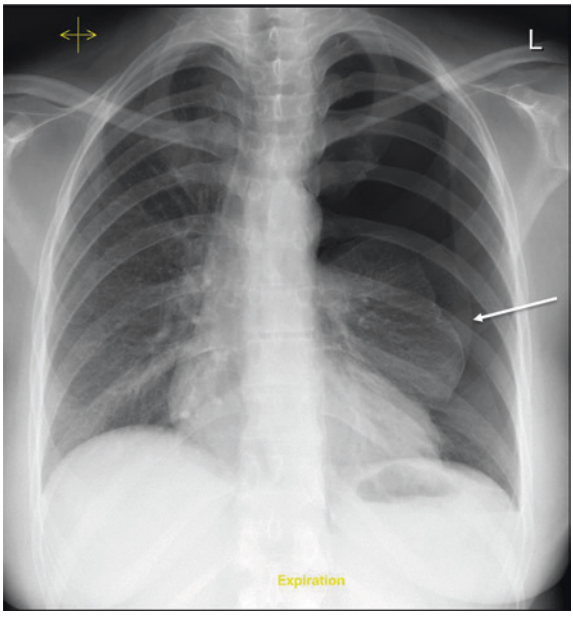

Fig. 3 Erect chest radiograph in a patient following blunt chest trauma. There is a large left-sided pneumothorax and the mediastinum has shifted to the right side, consistent with tension pneumothorax. The edge of the collapsed lung is highlighted with the white arrow

- The position of the mediastinum must be assessed in every case of pneumothorax, in order to assess for tension.
- Check for associated features: haemothorax, rib or sternal fractures or pneumomediastinum.

Haemothorax

- Bleeding into the chest cavity. May be from the chest wall, lung parenchyma or great vessels.
- Defined as massive if greater than 1,500 ml.
- The potential capacity of the thoracic cavity is significant, therefore a patient can lose a high volume of blood into the chest quickly, leading to hypovolemic shock and pulmonary compromise.

Haemothorax: Key imaging features

- Indisguisable from pleural effusion on chest radiograph. Blunting of costophrenic angles (if erect radiograph) or diffuse haze overlying hemithorax (if supine)
- Haemorrhage can be distinguished from simple effusion on CT by measuring the attenuation of the fluid. >30 Hounsfield units typically indicates blood products.

Aortic injury

- This can be rapidly fatal. Patients with a less severe injury such as mural haematoma or laceration are more likely to survive to hospital
- The thoracic aorta is relatively fixed at the isthmus, which is just distal to the left subclavian artery. There is a risk of transection at this point with a deceleration injury.

Aortic injury: Key imaging features

- Widened mediastinum on chest radiograph is a nonspecific sign with low sensitivity. Nonetheless it is important to assess for this, since almost all patients will have a chest radiograph as part of their primary survey.
- Haemorrhage tracking up along the left subclavian artery is called the apical cap sign on chest radiograph.
- Left sided haemothorax and/or depression of the left main bronchus.
- On CT, there may be an obvious injury but it may be a subtle irregularity of the aortic wall. Secondary signs include mediastinal haematoma.

Flail chest

- This is defined as two or more adjacent ribs fractured in at least two places.

- The rigid thoracic cage normally facilitates respiration. The result of a flail chest is a segment of chest wall which moves inwards (paradoxically) with inspiration, thus reducing air exchange in the lungs and causing significant pain.

Flail chest: Key imaging features

- Displaced rib fractures are usually obvious on chest radiograph (Fig. 4), however undisplaced fractures may be difficult to see.
- If a CT is obtained, look for associated injuries such as pneumothorax, pulmonary laceration (tear) or pulmonary contusion (which looks like lung infection, however the alveoli are filled with blood rather than inflammatory fluid—Fig. 5).
- 3D reconstruction of chest CT can be helpful in visualizing the ribs and identifying fail chest (Fig. 6).

Diaphragm injury

- Uncommon injury. Occurs in approximately 5% of major trauma cases
- More common on the left side, which may be due to the presence of the liver on the right.
- Abdominal contents may herniate into the thorax and reduce the functional capacity of the lung. The herniated abdominal organs are at risk of ischaemia.
- This can be a difficult diagnosis to make, even with advanced imaging such as CT. Some patients will therefore have a delayed diagnosis.

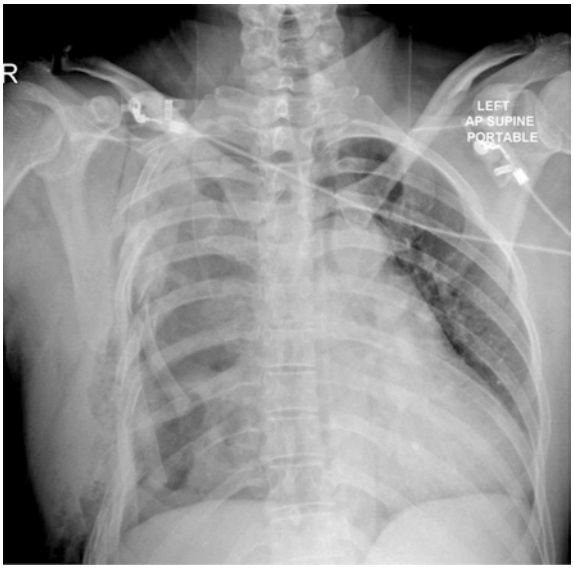

Fig. 4 Supine chest radiograph in a patient who fell from a horse. Multiple right-sided rib fractures, with at least two adjacent ribs fractured in two places, consistent with flail chest. Subcutaneous emphysema in the adjacent chest wall. Asymmetrical opacification of the entire right hemithorax suggests effusion/haemothorax (remember that this patient is lying flat, so fluid will not accumulate in the costophrenic angle as it would in an erect radiograph). The mediastinum is shifted to the left

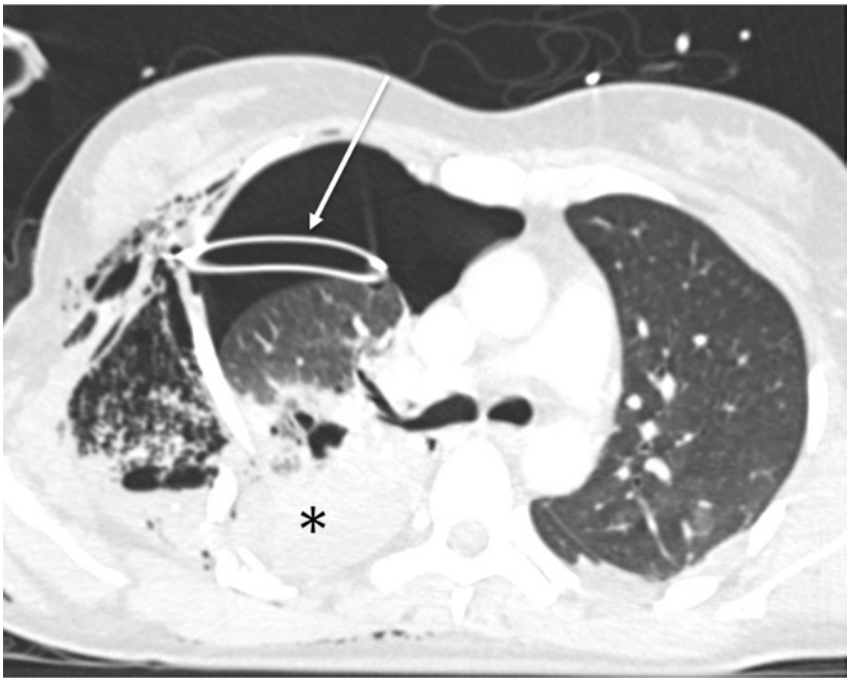

Fig. 5 Axial CT chest in the same patient as Fig. 4. This demonstrates a pneumothorax with a wide bore chest drain in situ (white arrow), collapsed lung with contusion (*) and displaced right sided rib fractures

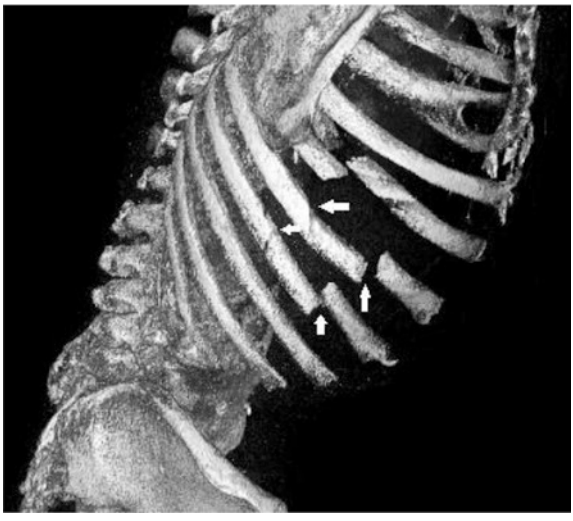

Fig. 6 3D reconstruction of a chest CT in a patient with flail chest. There is a displaced fracture of the right 7th rib and there are two fractures in each of the 8th and 9th ribs (arrows)

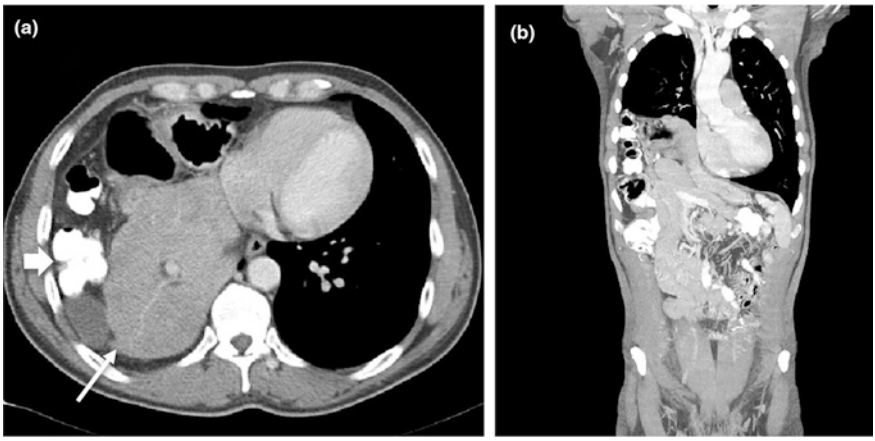

Fig. 7 Axial (**a**) and coronal (**b**) CT images from a patient with right sided diaphragm rupture. **a** With herniation of liver (thin arrow) and colon (thick arrow) into the thorax. The liver (thin arrow) has compressed and displaced the lung in the right costophrenic space and now appears to lie on the posterior ribs (the dependent viscera sign) **b** The right hemidiaphragm appears to extend more cranial than the left on the coronal CT due to the tear of the right diaphragm

Diaphragm injury: Key imaging features

- It can be difficult to visualise the diaphragm on plain radiography or CT because it is so thin, however new elevation of a hemidiaphragm or abnormal position of abdominal contents within the thorax can help make the diagnosis.
- Most important sign on CT of diaphragmatic rupture is the 'dependent viscera sign', where in a supine patient the liver or spleen are in abnormal contact with the ribs when the "sling function" of the diaphragm is lost (Fig. 7).

Common Patterns of Trauma: Abdomen

Solid organs: liver, spleen and kidney

- These are the most commonly injured intra-abdominal structures in blunt abdominal trauma. Injuries can be broadly divided into parenchymal haematoma, laceration and vascular injury.
- The American Association for the Surgery of Trauma (AAST) has published injury severity scores for multiple chest and abdominal organs, which are available freely online. The most widely used are for the liver and spleen (Table 1). The AAST system is useful when describing these complex injuries.
- Injuries to the renal tracts can be identified with delayed 'urographic' phase imaging. This is the phase during which intravenous contrast is being excreted by the kidneys, opacifying each ureter. Leakage of contrast during this phase signifies injury of the collecting system.

Table 1 American association for the surgery of trauma (AAST) classification for liver injury

Grade		
I	Haematoma	Subcapsular, <10% surface area
	Laceration	Capsular tear, <1 cm parenchymal depth
II	Haematoma	Subcapsular, 10–50% surface area intraparenchymal, <10 cm in diameter
	Laceration	Capsular tear, 1–3 cm parenchymal depth, <10 cm in length
III	Hematoma	Subcapsular, >50% surface area of ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma >10 cm or expanding
	Laceration	>3 cm parenchymal depth
IV	Laceration	Parenchymal disruption involving 25–75% hepatic lobe or 1–3 Couinaud's segments
V	Laceration	Parenchymal disruption involving >75% of hepatic lobe or >3 Couinaud's segments within a single lobe
	Vascular	Juxtahepatic venous injuries; i.e. retrohepatic vena cava/central major hepatic veins
VI	Vascular	Hepatic avulsion

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[a]Advance one grade for multiple injuries up to grade III

Key imaging features on CT

- Peri-splenic/peri-hepatic/peri-nephric haematoma.
- Intra-parenchymal haematoma.
- A laceration appears as a low attenuation region within the organ, usually extending to the organ capsule (Figs. 8 and 9).
- Vascular injury, which may range from complete avulsion of the organ hilum with active bleeding, to pseudoaneurysm or subtle vessel wall irregularity (Fig. 10 and Table 1).

Bowel Injury

- Intestinal injury typically occurs at a site of attachment to the mesentery, where an enteric structure is relatively fixed.
- Injury to bowel can be subtle on imaging and therefore is sometimes missed. This can have grave consequences if peritonitis occurs.
- Duodenal haematoma is commonly caused by blunt trauma to the epigastrium, such as from the handle bars of a bike. Pancreatic injury should also be suspected from this mechanism of injury.

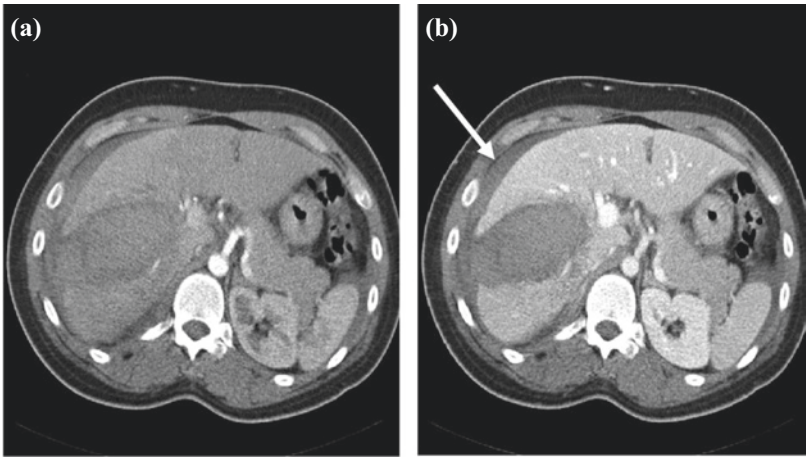

Fig. 8 Axial multiphasic CT liver (arterial and venous phases) of a patient following blunt trauma in a cycling accident. This is classified as AAST grade IV (laceration involving 25–75% of hepatic lobe). No active haemorrhage is demonstrated, however there is a crescent of high attenuation material surrounding the liver (see arrow), consistent with haemoperitoneum

Fig. 9 Axial CT of a patient following a fall from height. There is an AAST grade III splenic injury consisting of a parenchymal laceration (small arrow) and adjacent large subcapsular haematoma. There is also a high attenuation retroperitoneal haematoma anterior to the right kidney (long arrow)

Bowel Injury: Key imaging features

- Hemoperitoneum (often the only indication of visceral injury).
- Mesenteric fat stranding.
- Bowel wall thickening/mural haematoma.
- Free intra-abdominal air.

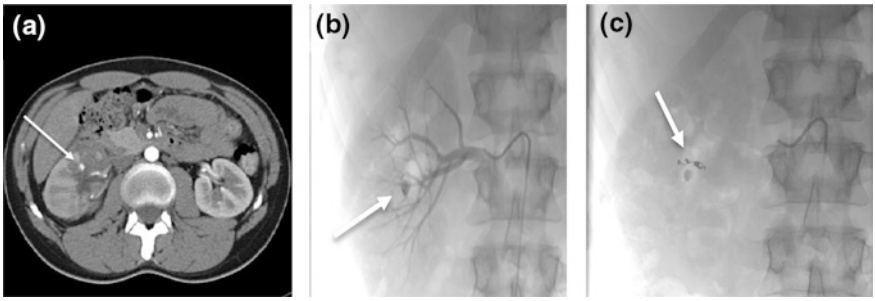

Fig. 10 **a** Right renal laceration post snowboarding injury. Image **a** is the arterial phase and **b** is the venous phase. There is an arterial enhancing structure within the site of injury (see arrow), consistent with a pseudoaneurysm (PsA). This was treated by Interventional Radiology by angiography and embolization. **b** Angiographic image from the IR embolization procedure, demonstrating the PsA (arrow). **c** Post embolization image showing metallic coils (arrow) which have been placed across the site of renal arterial branch injury

Management—The Role of Interventional Radiology

- Interventional Radiology plays an important role in the management of major haemorrhage.
- Typically patients will first undergo CT angiography in order to identify the site of haemorrhage. Patients who are acutely unstable despite resuscitation are usually managed by open surgery.
- In patients who are stable, or in those unstable patients who respond to resuscitation, haemorrhage may be managed by Interventional Radiology with embolization or stenting of a damaged artery.
- Common procedures in trauma include: Thoracic Aortic transection stent graft placement, embolic occlusion of the splenic artery for splenic laceration, selective repair of transected arteries or artery embolisation at suitable sites such as pelvic fractures, liver or renal laceration

Suggested Reading

- Gore R, Levine M. Textbook of gastrointestinal radiology, 4th ed. Elsevier; 2015.
- Major trauma: assessment and initial management. NICE guideline NG39. February 2016.
- Advanced trauma life support. Student course manual, 10th ed. 2018.
- AAST Injury Severity Scores: http://www.aast.org/library/traumatools/injuryscoringscales.aspx#spleen.
- Royal College of Radiologists (RCR) Standards of practice and guidance for trauma radiology in severely injured patients, 2nd ed. 2015.
- Soto JA, Anderson SW. Multidetector CT of blunt abdominal trauma. Radiology. 2012;265:678–93.