The role of plain films in imaging major trauma

This article reviews the role of imaging in the management of trauma patients. First the trauma series is reviewed, principally the chest, pelvis and cervical spine radiographs along with an approach to their interpretation. The role of computed tomography in trauma imaging is then discussed.

The primary assessment of a person who is critically injured from major trauma is a challenging task and recognition of patterns of major trauma has led to the development of advanced trauma life support (Sauaia et al, 1995; American College of Surgeons, 2004). Advanced trauma life support is the standard of care for trauma patients and is built around a standardized protocol for patient evaluation. The objectives are primarily:

1. Stabilize the patient
2. Identify life-threatening injuries and initiate adequate supportive therapy
3. Efficiently and rapidly organize definitive therapy or transfer to a facility that provides definitive therapy (Moore et al, 2004; Parks, 2004).

The initial evaluation follows a protocol of primary survey, resuscitation, secondary survey and either definitive treatment or transfer to an appropriate trauma centre for definitive care. The steps of the primary survey are encapsulated by the mnemonic ABCDE (airway, breathing, circulation or haemorrhage, disability and exposure or environment). The secondary survey commences after completing the primary survey and starting the resuscitation phase. At this time, all injuries should be identified by conducting a thorough head-to-toe examination. Radiology provides crucial diagnostic information that guides and supplements the initial evaluation.

This article will review the role of imaging in the management of trauma patients. There will be emphasis on the plain radiograph trauma series together with an approach to interpretation and then the role of computed tomography in trauma will also be discussed.

Plain radiographs: the basic trauma series

The basic trauma series consists of the anteroposterior chest, pelvis and 'cross table' lateral cervical radiographs. These will complement a thorough physical examination and indicate the need for further imaging, in particular computed tomography.

Dr Christopher J Burke *is Specialist Registrar in Radiology,* **Dr Robert H Thomas** *is Specialist Registrar in Radiology,* **Dr Emma Owens** *is Consultant Radiologist and* **Dr David Howlett** *is Consultant Radiologist, Eastbourne District General Hospital, Eastbourne BN21 2UD*

Correspondence to: Dr CJ Burke

The chest radiograph

The anteroposterior chest radiograph is usually the first imaging study performed on trauma patients. It can be readily obtained during the resuscitation phase and provides information on the presence of a rib fractures (*Figure 1* – yellow arrows), haemothorax, pneumothorax or pulmonary contusion. The anteroposterior chest radiograph also evaluates placement of chest and endotracheal tubes, which are critical to the resuscitation effort and the primary survey. Unfortunately because of the condition of the patient, radiographs are often supine which magnifies the mediastinum, making assessment difficult.

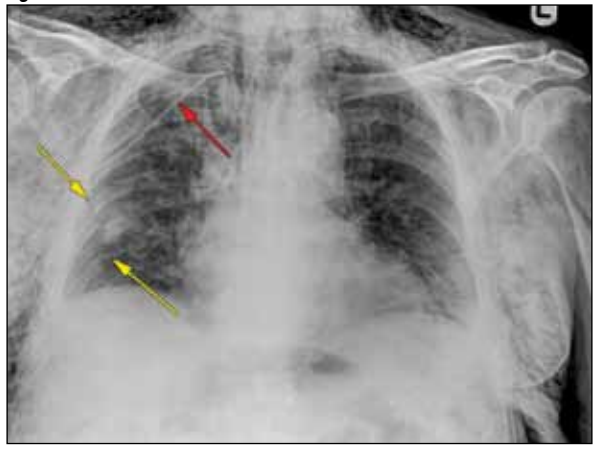
Interpreting the chest radiograph

First confirm that the film being viewed is of diagnostic quality. There should be sufficient coverage of the whole chest (from thoracic inlet to diaphragm and including both lateral chest walls). Note should also be made of tubes or lines (*Figure 1* – intercostal drain, red arrow).

Pleural spaces and lung parenchyma

Assess the pleural space for abnormal collections of fluid that may represent a haemothorax. Then assess for abnormal collections of air that may represent a pneumothorax, usually seen as a lucent area without bronchial or vascular markings (*Figure 2*).

Figure 1. Anteroposterior chest radiograph demonstrating marked surgical emphysema extending bilaterally over the thorax. There are multiple right-sided rib fractures (yellow arrows). Note the right intercostal drain (red arrow).



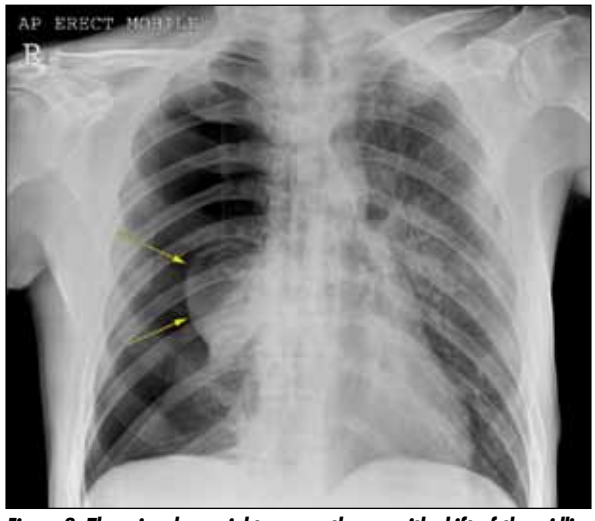


Figure 2. There is a large right pneumothorax with shift of the midline to the contralateral left side suggesting it is under tension. The edges of the collapsed right lung are outlined with yellow arrows.

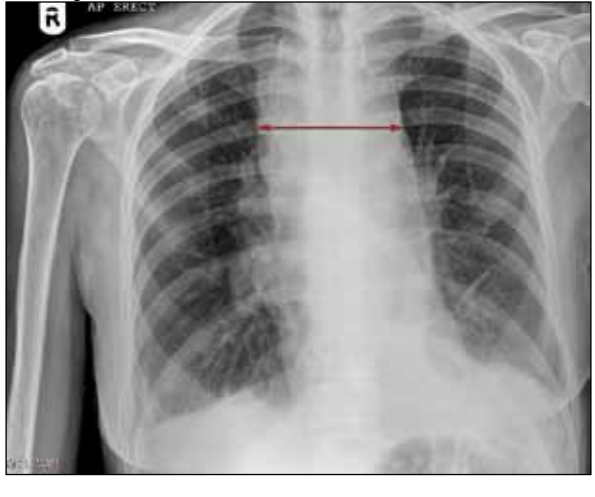
Note that a small pneumothorax in a supine patient may be difficult to identify.

Assess the lung fields for infiltrates that may suggest pulmonary contusion, haematoma or aspiration. Pulmonary contusion appears as air space consolidation that can be irregular and patchy, homogenous, diffuse or extensive.

Mediastinum

Look for air or blood that may displace mediastinal structures and blur the demarcation between tissue planes or outline them with radiolucency. Air or blood in the pericardium may cause an enlarged cardiac silhouette. Progressive changes in cardiac size may represent an expanding pneumopericardium or haemopericardium. Aortic rupture may be suggested by a widened mediastinum – this is the most reliable finding (*Figure 3*).

Figure 3. Plain chest radiograph demonstrating a widened mediastinum. Despite the anteroposterior projection which magnifies the mediastinum, the double-ended arrow demonstrates the margin of the widened mediastinum.



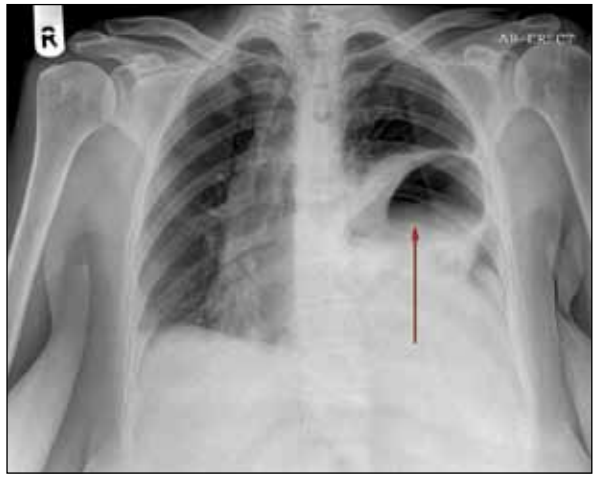


Figure 4. Chest radiograph in a patient with a ruptured left hemidiaphragm, which is markedly elevated. Note the gastric bubble (red arrow) within the left hemithorax.

Diaphragm

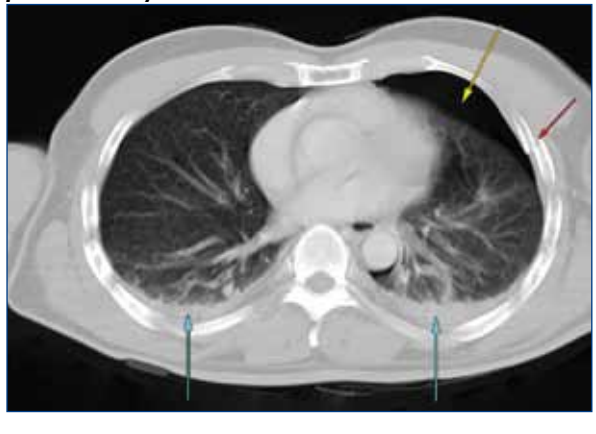
Diaphragmatic rupture requires a high index of suspicion, based on the mechanism of injury, the patient's signs and symptoms, and X-ray findings (*Figure 4*). Evaluate the diaphragm for:

- Elevation, irregularity or obliteration of the diaphragm
- Disruption (stomach, bowel gas or nasogastric tube above the diaphragm)
- Poor identification (irregular or obscure) because of overlying fluid or soft tissue masses.

Bony thorax

Ribs: Assess for evidence of fractured ribs (*Figure 5*). In particular look for fracture of two or more contiguous ribs in two places (flail chest) or associated injury, e.g. pneumothorax, haemothorax or pulmonary contusion, spleen, liver and/or kidney. Fracture of the first and second ribs indicates significant trauma with increased risk of great vessel injury.

Figure 5. Axial computed tomography image (set on bone windows) demonstrating fractures of the mid left ribs (red arrow) with atelectatic change postero-basally in the lower lobes with small basal effusions (blue arrows). There is a moderate left-sided pneumothorax (yellow arrow).



Clavicle and scapula: Assess for evidence of fracture or associated injury, e.g. great vessel injury with the clavicle and airway or great vessel injury, or pulmonary contusion with the scapula.
Sternum: Assess the sternomanubrial junction and sternal body for evidence of fracture or dislocation, best seen on a lateral view or computed tomography.

Soft tissues

Assess for displaced or disrupted tissue planes or evidence of subcutaneous air (*Figure 1*).

Tubes and lines

Assess for placement and positioning of endotracheal tube, intercostal drain (*Figure 1*), central access lines, nasogastric tubes and other monitoring devices (*Table 1*).

Pelvis

In the primary assessment of the trauma patient a plain portable anteroposterior pelvis film is easily obtained and can confirm the presence of significant pelvic fractures, which may be the sites of haemorrhage and may require external fixation and/or angiographic embolization for control (Burgess and Jones, 1996; Kessel et al, 2007).

Assess for pelvic ring fractures caused by high-energy blunt trauma. Look at the ilium, ischium, pubic rami and acetabuli for evidence of fracture (*Figure 6*), and the pubic symphysis for evidence of diastasis (*Figure 7*) (Kellam and Browner, 1998; Young, 1998; Scalea and Burgess, 2000).

Table 1. Plain film X-ray findings with associated diagnoses to consider

Findings	Diagnoses to consider
Respiratory distress without X-ray findings	CNS injury, aspiration, traumatic asphyxia
Any rib fracture	Pneumothorax, pulmonary contusion
Fracture lower ribs 9 to 12	Abdominal injury
Two or more rib fractures in two or more places	Flail chest, pulmonary contusion
Scapular fracture	Great vessel injury, pulmonary contusion, brachial plexus injury
Sternal fracture	Blunt cardiac injury
Mediastinal widening	Great vessel injury, sternal fracture, thoracic spine injury
Persistent large pneumothorax on air leak after chest tube insertion	Bronchial tear
Mediastinal air	Oesophageal disruption, tracheal injury, pneumoperitoneum
Gastrointestinal gas pattern in the chest (loculated air)	Diaphragmatic rupture
Nasogastric tube in the chest	Diaphragmatic rupture or ruptured oesophagus
Air fluid level in the chest	Haemothorax or diaphragmatic rupture
Disrupted diaphragm	Abdominal visceral injury
Free air under the diaphragm	Ruptured hollow abdominal viscus

Adapted from American College of Surgeons (2004)

Cervical spine

Cervical spine radiographs are indicated in all trauma patients who have midline neck pain, palpation tenderness, neurological deficits referable to the cervical spine, an altered level of consciousness, are suspected of being intoxicated or who have distracting injuries (Hoffman et al, 1998; Stiell et al, 2003).

If cervical spine injury is suspected three standard views are obtained: lateral, odontoid 'peg' view, and anteroposterior (with an additional swimmer's view if the lower cervical vertebra and cervicothoracic junction cannot be seen on the lateral). These three standard views may also be supplemented by computed tomography (as discussed later) if there is a high index of suspicion for injury but no fracture is seen on plain radiographs.

An adequate lateral cervical spine X-ray (e.g. visualizing from the skull base to T1) helps identify most cervical spine fractures and subluxations (Raby et al, 2005).

Figure 6. Plain radiograph of pelvis shows fractures of left superior and inferior pubic rami (yellow arrows). There is also a fracture through the right iliac wing (blue arrows).

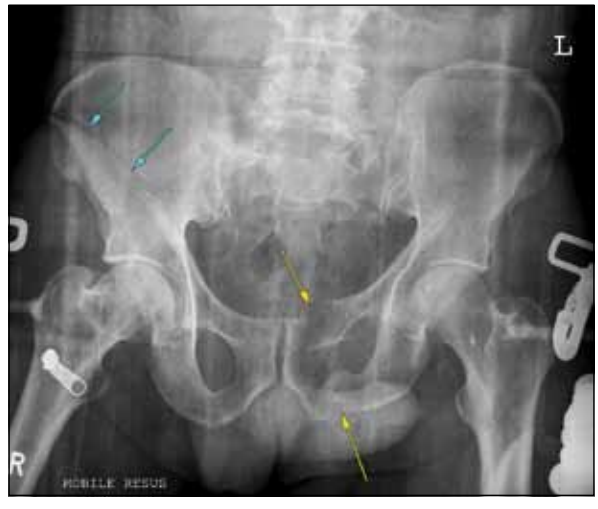


Figure 7. Plain pelvic radiograph shows post-traumatic separation at the symphysis pubis (double-ended small arrow).

Interpreting the cervical spine radiograph

Cross-table lateral view

On the lateral view, the base of the skull, all seven cervical vertebrae and the first thoracic vertebra must be visualized to avoid missing fractures in the lower cervical spine (*Figure 8*) and fracture dislocations at C7/T1.

The patient's shoulders may have to be pulled down when obtaining the lateral cervical spine X-ray or a swimmer's view obtained (where one arm is raised or pulled in order to project the humeral head clear of the lower cervical spine anatomy) to visualize the cervicothoracic junction. Failure to clearly visualize these areas may result in missed injuries.

Figure 8. Lateral cervical spine radiograph showing a fracture of the spinous process of C7 or a 'clay shoveler's' fracture (yellow arrow).

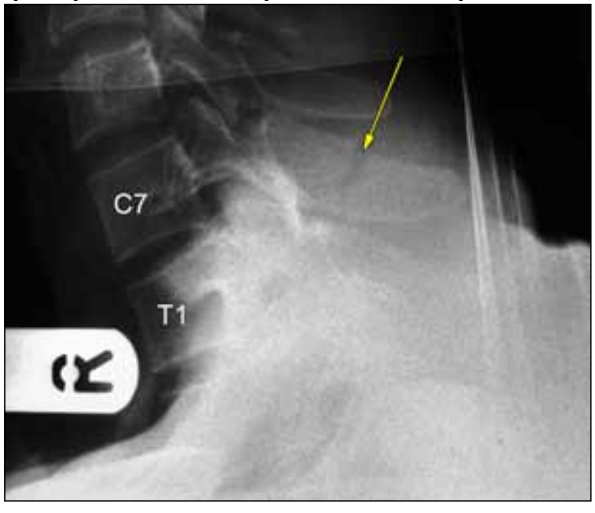
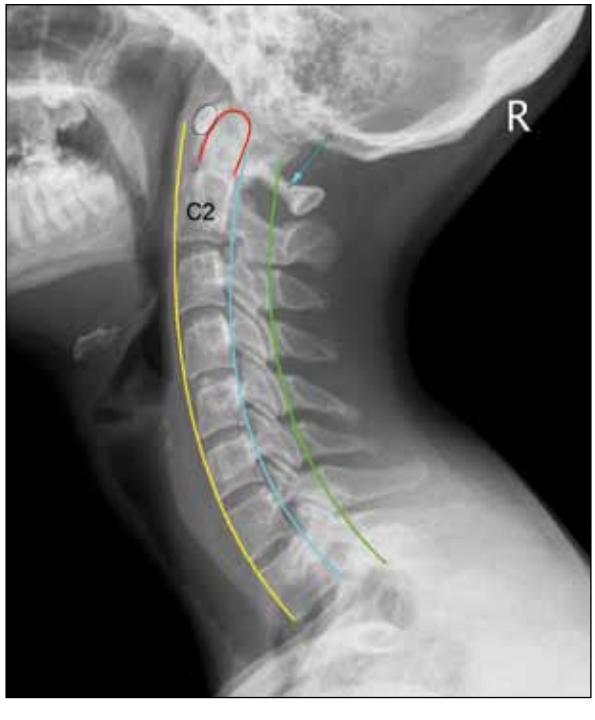


Figure 9. Normal lateral cervical spine radiograph demonstrates the three lordotic curves. The odontoid peg is outlined in red and the anterior arch of atlas (C1) is circled.



Three lordotic curves

The alignment of the cervical spine is assessed by tracing three imaginary contour lines (*Figure 9*).

1. The first line connects the anterior margins of all the vertebrae and is referred to as the anterior vertebral line (yellow curve)
2. The second line should connect the posterior aspect of all vertebrae in a similar way and is referred to as the posterior vertebral line (blue curve)
3. The third line should connect the bases of the spinous processes and is referred to as the spinolaminar line (green curve) (Raby et al, 2005).

Each of these lines should form a smooth lordotic curve. Bony or ligamentous injury should be suspected if these contour lines are disrupted (*Figures 10* and *11*).

The vertebral bodies

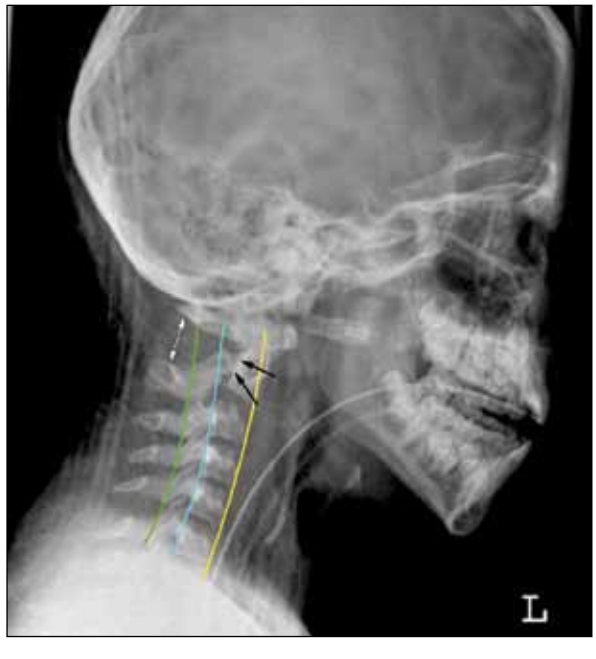
Assess each vertebra for obvious fracture or changes in bone density. Focal areas of decreased bone density are seen in patients with osteoporosis, osteomalacia or osteolytic lesions and may represent weak areas predisposed to injury. Areas of increased bony density may represent compression fractures.

The vertebral bodies and intervertebral discs should be of uniform height. If the anterior height of a vertebral body is ≥3 mm less than the posterior height, this is suspicious for a wedge-compression fracture.

The predental and prevertebral space

Look at the predental space (also known as the atlantodental interval). This is the distance between the anterior aspect of the odontoid and the posterior aspect of the

Figure 10. Lateral cervical spine radiograph shows a hangman's fracture. Note the disruption of the lordotic curves and fracture through the pars interarticularis of the C2 vertebra. This injury is unstable.



anterior arch of C1, and should be no more than 3 mm in an adult and 5 mm in a child. Suspect transverse ligament disruption if these limits are exceeded.

Prevertebral space extends between the anterior border of the vertebra to the posterior wall of the pharynx in the upper vertebral level (C2–C4) or to the trachea in the lower vertebral level (C6). At the level of C2, the prevertebral space should not exceed 7 mm. At the level of C6, the prevertebral space is widened by the presence of the oesophagus and cricopharyngeal muscle. At this level, the space should be no more than 22 mm in adults or 14 mm in children younger than 15 years (Raby et al, 2005).

If the prevertebral space is widened at any level, a haematoma secondary to a fracture should be suspected (*Figure 12*) (Raby et al, 2005).

Odontoid view

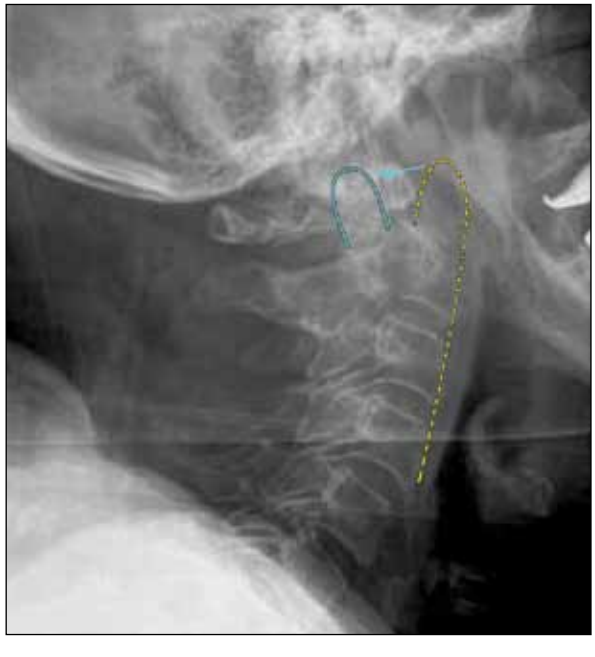
The open mouth odontoid (peg) view should include the entire odontoid process and the right and left C1 and C2 articulations (*Figure 13*). Masses should be bilaterally symmetrical with the dens and odontoid process. Look for fractures or lateral displacement. The lateral masses of C1 should not overhang the lateral masses of C2. If present, this is indicative of a burst fracture (*Figure 14*).

Anteroposterior view

A straight line should connect the spinous processes bisecting the cervical spine. If this is not seen, consider a rotation injury (i.e. unilateral facet dislocation).

The distance between the spinous processes should be equal. No space should be 50% wider than the one immediately above or below it. If so, this is characteristic of an anterior cervical dislocation.

Figure 11. Lateral cervical spine radiograph demonstrates a fracture of the odontoid peg of C2. This injury is unstable. There is again disruption of the lordotic curves.



Focused abdominal sonogram

The focused abdominal sonogram for trauma (FAST) scan complements the portable chest and pelvis films (American College of Surgeons, 2004). It is used princi-

Figure 12. Lateral cervical spine radiograph with the patient strapped down to blocks for immobilization causing artefact. There is marked widening of the prevertebral space (see double-ended arrows). Although no fracture is identified a haematoma secondary to an occult fracture should be suspected. This radiograph is inadequate (with the lower cervical spine not visualized – blue curved line) and the patient should be further imaged using computed tomography.

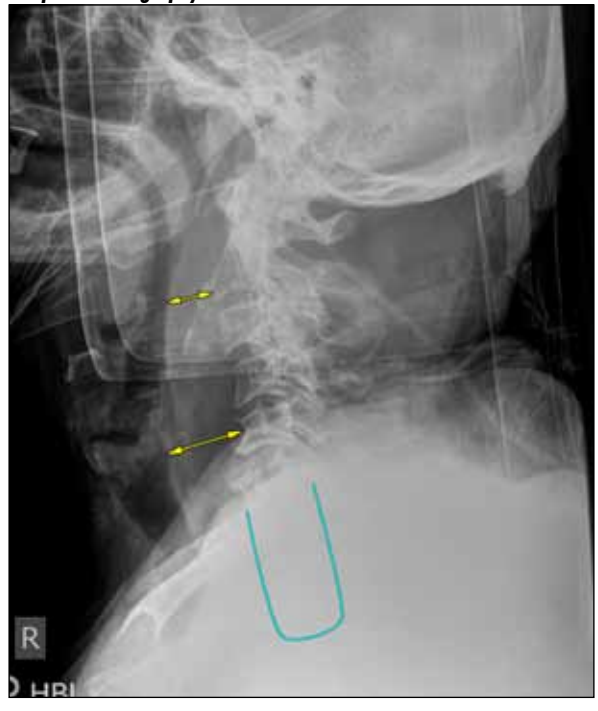
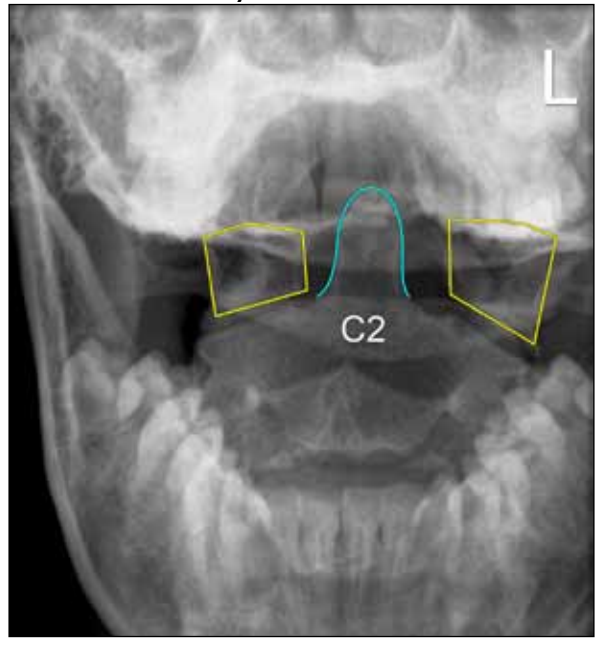


Figure 13. Normal peg view. The peg is outlined in blue and the lateral masses outlined in yellow.



pally to identify blood or free fluid in the peritoneal cavity and is useful for the rapid assessment of unstable trauma patients because of its speed, sensitivity and non-invasive character.

The role of computed tomography

The computed tomography scan is the definitive radiographic study in most patients with significant trauma. The patient must be clinically stable before transfer for computed tomography.

Cervical spine computed tomography

Computed tomography imaging of the cervical spine is increasingly being used where abnormalities are identified on plain radiographs or where plain radiograph findings are negative but clinical suspicion for fracture remains high. Computed tomography scanning is useful in further evaluating cervical spine trauma where plain films are of poor diagnostic quality or where the cervicothoracic junction cannot be seen. Computed tomography improves detection of fractures when compared to the standard series of cervical spine radiographs.

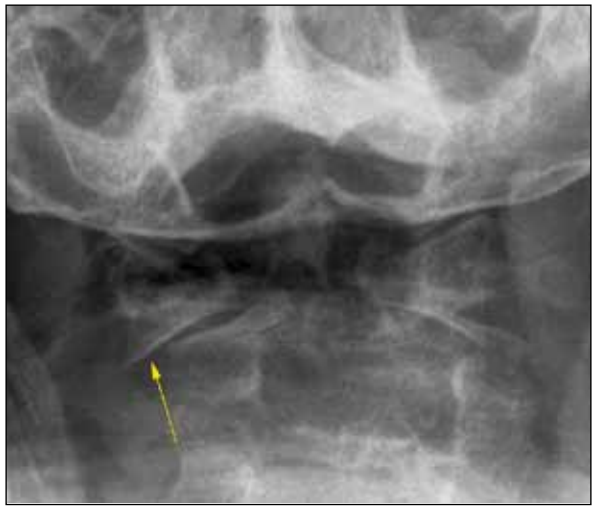
The same views generated by plain radiography (anteroposterior, lateral, open mouth) are generated via computed tomography.

Body computed tomography in trauma

Computed tomography imaging of the abdomen, pelvis, chest and head is the most sensitive and accurate non-invasive diagnostic tool for visceral injury.

A computed tomography scan of the chest should be obtained to evaluate suspected mediastinal injuries. Computed tomography aortography is the study of choice for imaging mediastinal vascular structures and computed tomography is also more sensitive than chest radiography in the detection of pneumothorax, rib fractures (*Figure 5*), pulmonary contusion, and hydrothorax.

Figure 14. Odontoid view demonstrating displacement of the lateral masses, particularly on the right (see yellow arrow). There is a burst or Jefferson fracture of C1.



Computed tomography scans of the abdomen and pelvis usually are performed together. This can identify injuries to abdominal and pelvic organs and bleeding within the retroperitoneum and pelvis (*Figures 15* and *16*).

Computed tomography of the head

Computed tomography of the head is indicated in severe head injury (Glasgow Coma Scale less than or equal to 8) and moderate head injury (Glasgow Coma Scale 9–12) (National Institute for Health and Clinical Excellence, 2007). National Institute for Health and Clinical Excellence guidelines now recommend that head computed tomography should also be performed where:

- Glasgow Coma Score <13 when first assessed or Glasgow Coma Score <15 2 hours after injury
- Suspected open or depressed skull fracture
- Signs of base of skull fracture (haemotympanum, 'panda' eyes (bruising around the eyes), CSF leakage (from the ears or nose) or Battle's sign (bruising which can occur behind the ear in cases of basal skull fracture)) (National Institute for Health and Clinical Excellence, 2007)
- Post-traumatic seizure
- Focal neurological deficit

Figure 15. Contrast-enhanced axial computed tomography demonstrates a laceration of the liver (yellow arrows).

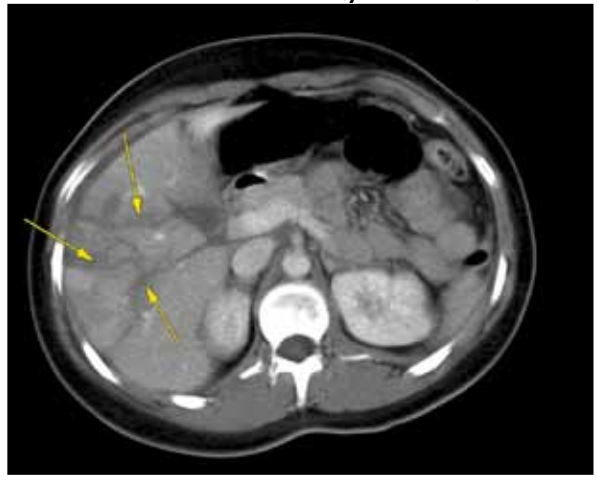
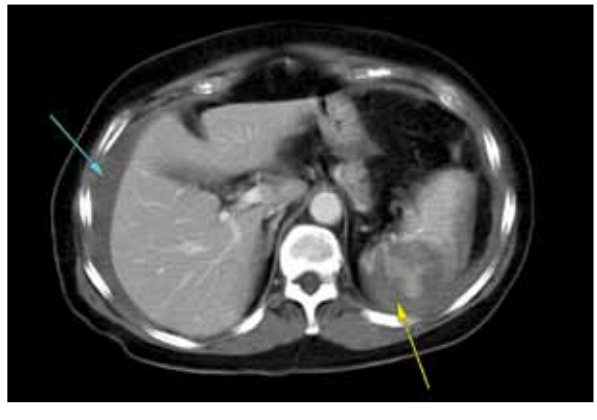


Figure 16. Contrast-enhanced axial computed tomography shows a splenic laceration with formation of haematoma (yellow arrow). Note the presence of blood surrounding the liver (blue arrow).



- One or more episodes of vomiting
- The patient has a coagulopathy and any amnesia or loss of consciousness since injury.

A computed tomography scan is also recommended if there is either:

- Over 30 minutes of amnesia of events before impact

Or any amnesia or loss of consciousness since injury if:

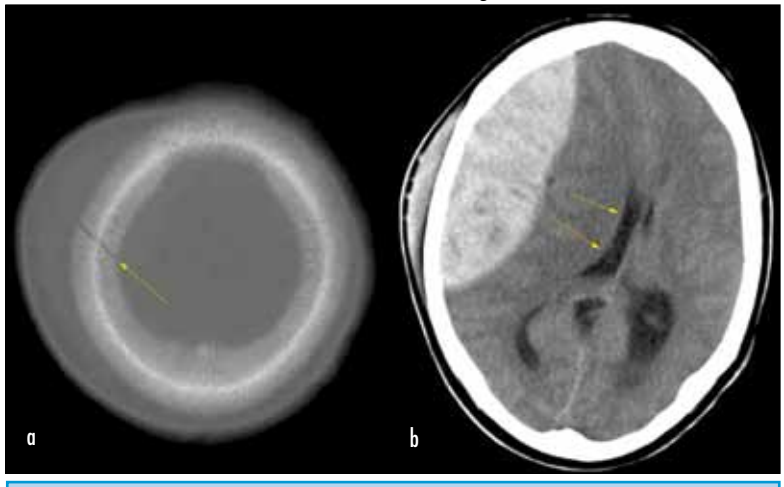
- Aged ≥65 years
- The patient has a coagulopathy or is on warfarin
- Dangerous mechanism of injury
- Road traffic accident as a pedestrian or ejected from car
- Fall >1 m or >five stairs.

Computed tomography is the investigation of choice for demonstration of skull fractures (*Figure 17a*), intracranial haemorrhage (extradural – *Figure 17b*, subdural – *Figure 18* or intra-parenchymal) or air within the cranial vault. Computed tomography is especially useful to identify fractures of the skull base.

Conclusions

Radiology plays an integral role in the management of the critically injured patient. The plain trauma series remains an important tool in the primary management of injured patients, but with improved access to computed tomography, considerably more diagnostic information can be obtained relatively quickly. National guidelines are also in place to guide the use of computed tomography, particularly with regard to head injury. BJHM

Figure 17. a. Non-contrast axial computed tomography (bone windows) demonstrating a linear non-depressed skull fracture through the right parietal bone with a large overlying subcutaneous haematoma. b. Non-contrast axial computed tomography (soft tissue windows) in the same patient showing a large extradural haematoma causing significant mass effect with midline shift and effacement of the right lateral ventricle (see arrows).



KEY POINTS

- The plain film trauma series and computed tomography play a crucial role in the assessment of the injured patient.
- An understanding of the spectrum of radiological abnormalities is crucial for rapid diagnosis and management.
- Early liaison with radiology will promote improved imaging and therefore patient care.

Conflict of interest: none.

American College of Surgeons (2004) *Advanced Trauma Life Support Program for Physicians.* 7th edn. American College of Surgeons, Chicago, IL

Burgess AR, Jones AL (1996) Fractures of the pelvic ring. In: Rockwood CA, Green DP, Bucholz RW, Heckman JD, eds. *Rockwood and Green's Fractures in Adults.* 4th edn. Lippincott, Philadelphia: 1575–615

Hoffman JR, Wolfson AB, Todd K, Mower WR (1998) Selective cervical spine radiography in blunt trauma: methodology of the National Emergency X-Radiography Utilization Study (NEXUS). *Ann Emerg Med* **32:** 461–9

Kellam JF, Browner BD (1998) Fractures of the pelvic ring. In: Browner BD, Jupiter JB, Levine AM, Trafton PG, eds. *Skeletal Trauma: Fractures, Dislocations, Ligamentous Injuries.* 2nd edn. WB Saunders Co, Philadelphia: 1117–79

Kessel B, Sevi R, Jeroukhimov I, Kalganov A, Khashan T, Ashkenazi I (2007) Is routine portable pelvic X-ray in stable multiple trauma patients always justified in a high technology era? *Injury* **38**(5): 559–63

Moore EE, Feliciano DV, Mattox KL (2004) *Trauma.* 5th edn. McGraw-Hill Publishers, New York

National Institute for Health and Clinical Excellence (2007) *Triage, assessment, investigation and early management of head injury in infants, children and adults.* NICE Clinical Guideline. www.nice.org.uk/CG056 (accessed 20 September 2010)

Parks SN (2004) Initial assessment. In: Moore EE, Feliciano DV, Mattox KL, eds. *Trauma.* 5th edn. McGraw-Hill Publishers, New York: 159–75

Raby N, Berman L, de Lacey G (2005) *Accident and Emergency Radiology: A survival guide.* 2nd edn. Saunders, Philadelphia

Sauaia A, Moore FA, Moore EE, Moser KS, Brennan R, Read RA (1995) Epidemiology of trauma deaths: a reassessment. *J Trauma* **38**(2): 185–93

Scalea TM, Burgess AR (2000) Pelvic fractures. In: Mattox KL, Feliciano DV, Moore EE, eds. *Trauma.* McGraw-Hill Pub, New York: 807–37

Stiell IG, Brison R, Schull MJ et al (2003) The Canadian C-Spine Rule versus the NEXUS low-risk criteria in patients with trauma. *N Engl J Med* **349**(26): 2510–18

Young JW (1998) Pelvic injuries. *Semin Musculoskelet Radiol* **2**(1): 83–104

Figure 18. Non-contrast axial computed tomography scan demonstrating a post-traumatic subdural haemorrhage with significant mass effect and midline shift. The arrows delineate the margin of the subdural haematoma.