Guidelines for imaging children who have suffered major blunt trauma have been produced by a sub-group of the British Society of Paediatric Radiologists (BSPR). These were developed after it was recognised that children are ‘not just small adults’ and have different injury patterns. This is due to differences in relative anatomical proportions (for example, small children have a relatively larger head), an unfused skeleton and greater tissue elasticity, but more importantly children are more sensitive to the effects of ionising radiation (IR), with longer to live and children are more sensitive to the effects of ionising radiation (IR), with longer to live and develop radiation induced cancers.

Children presenting with major complex polytrauma should be imaged with a pan-body CT, but the recommendations suggest pre-assessment plain films of the cervical spine and chest when there is a low clinical suspicion for significant injury, to identify whether a cervical or thoracic CT is required. CT is always recommended as the first line imaging for potential abdominal injury.

As a general rule, the majority of children under eight years of age (25-60%) suffer major trauma as a consequence of road traffic accidents (usually as car passengers), whereas older children tend to be hurt as a result of falls or sports-related injuries. Non-accidental injury must be remembered when the mechanism of injury is unclear, particularly with very small children, and when bowel injury is suspected.

Ultrasound

Many clinicians regard ultrasound as an excellent screening tool for significant abdominal injury. Although, this may be agreed locally, the national guidelines do not recommend this as first line imaging because of the relatively low sensitivity for identifying visceral lesions (at best 82%). Perhaps future technological advances, including microbubble contrast enhancement, will lead to a change in guidance advice, and such developments are eagerly anticipated.

CT

There are several clinical inclusion criteria for abdominal and pelvic CT (Table 1). It is important to remember to scan both the abdomen and pelvis since a small volume of free fluid in the pelvis may be the only indicator of significant intra-abdominal pathology.

CT is used to identify possible hemorrhage and the site and size of injury, and also to determine whether surgical intervention is necessary and guide non operative decisions such as duration of hospitalisation, intensity of treatment and length of activity restriction.

Optimising contrast opacification

When planning the CT scan it is important to consider the timing of the contrast injection to ensure optimal visceral enhancement. Penetrating injuries are occasionally encountered in this age group and necessitate arterial phase imaging, whereas both arterial and venous contrast enhancement are required when imaging injury secondary to blunt abdominal trauma.

Imaging should always adhere to the ALARA principle – as low as reasonably achievable – and in recent years there has been increasing anxiety regarding the high IR dose delivered by CT. This has seen a move to dual bolus single acquisition (DBSA) contrast enhancement when both arterial and venous enhancement is obtained in a single acquisition. However, many clinicians feel that this method of contrast enhancement is inappropriate since it may lead to confusion when trying to differentiate between the arterial and venous hemorrhage and plan future management.

It should be remembered that children and young people have an enhanced vasoconstrictor response, with a spontaneous cessation of bleeding whatever the grade of laceration, and non operative conservative management is appropriate for the majority of cases. Ruess et al followed 122 children over a 10-year period and found that only 3% of hepatic and 2% of splenic injuries required a laparotomy. Similarly Stylianos identified 316 children with an isolated grade I-IV hepatic or splenic injury, and found that only 1% of them required a laparotomy.

Thus there may be no active haemorrhage at the time of scanning – although bleeding may recommence at a later time – and imaging with separate arterial and venous phase scans could be falsely reassuring and deliver twice the IR dose of DBSA-CT. Regardless of the mode of contrast enhancement employed it is recommended that all children be monitored closely in the first 24 hours following complex polytrauma for signs of persisting hypotension.

There are various strategies for optimal timing with DBSA-CT but in general one-third of the contrast should be given slowly over approximately 50 seconds and the final one-third rapidly over the remaining 10-15 seconds before commencing the scan. To facilitate this, pump injection is recommended, although hand injection may be more appropriate for small children. While this results in excellent contrast enhancement for the majority of children, a predominantly arterial phase scan is occasionally encountered, and it is thought that this is secondary to haemodynamic instability, with delayed venous return.

Oral contrast should not be given. Firstly the patient should be nil by mouth and secondly bowel paralysis often occurs, even without significant injury, with an increase in intraluminal fluid; contrast enhancement of the bowel wall may also be seen.

Visceral injury

When reporting CT examinations many radiologists grade the visceral injury using trauma scores developed by the American Association for the Surgery of Trauma (AAST) which can be looked up online at the AAST website (http://www.aast.org/library/traumatools/injuriouscoringcales.aspx). Different grades of laceration are given for each organ but, as already mentioned, it is of utmost importance to identify any active haemorrhage.

Injuries identified radiologically may be lacerations,
haematomas or vascular events. Lacerations vary from simple linear ‘fractures’ to complex branching injuries which extend across an organ for a variable length and may result in complete visceral disruption, when the organ is described as ‘shattered’. Similarly haematomas vary in size and position, and may be parenchymal or subcapsular, isolated or associated with lacerations. Vascular injuries are rare in children but intimal tears may cause arterial occlusion with a corresponding area of devascularisation. Rapid recognition is required so that intervention may be considered.

Of the solid organs, the spleen is most commonly injured, followed by the liver; it should be noted that splenic involvement is also seen in approximately 10% of hepatic trauma. The kidneys are less commonly injured (~10%) and pancreatic injury is relatively uncommon, but does carry a high morbidity and mortality. It is also associated with multiple visceral injuries; hepatic, splenic and renal. The other abdominal organs are less frequently involved.

Between 1-5% of severe trauma is associated with adrenal haemorrhage, with the right-sided gland being more commonly affected. There is some indication that this may be due to arterial spasm rather than direct trauma.

Bowel injury is uncommon but is three times as common when secondary to non-accidental injury. It may be very difficult to identify and in approximately one-third of children the CT findings are simply of a moderate to large volume of free fluid. Intramural haematomas or bowel rupture may occur, with the duodenum being the commonest location for intramural haematomas, whereas bowel rupture usually occurs in the jejunum and mid to distal small intestine.

Trauma to the abdominal aorta is rarely seen but approximately 70% are intimal dissections, and pseudo aneurysms may develop as in the adult population.

Bladder injury is also uncommon. Urine within the extraperitoneal space (located in the peri-vesical space anteriorly and superiorly, and posterior to the rectum) results from internal laceration by a bone fragment from a pelvic fracture, and may be managed conservatively. Intraperitoneal rupture (fluid is located in the lateral peri-vesical space, and anterior to the recto-sigmoid junction) is usually as a consequence of sheering forces, such as with a seatbelt injury and, conversely, requires immediate surgical repair; fortunately the latter is less common.

The seat belt syndrome
The use of seat belts has dramatically reduced the risk of fatal and serious injury, but when incorrectly positioned across a child’s abdomen (they should be positioned low across the thighs) can result in internal injuries. The seat belt syndrome is a triad of anterior abdominal wall bruising with intra abdominal injuries along the line of compression including visceral lacerations, mesenteric haematomas, and spinal distraction injury. Clinically it should be suspected in any child following an appropriate mechanism with anterior abdominal wall bruising along the line of the seat belt and with tenderness on abdominal palpation.

The hypoperfusion complex (shocked bowel)
This is a spectrum of CT appearances that is thought to be haemodynamically driven. Originally assumed to be due to hypovolaemia there is increasing evidence that this results from disruption to the nervous system – due to upset of the autonomic system, impaired sympatho-adrenal output, reduced myocardial contractility or diminished peripheral vascular resistance – since it may occur with severe neurological impairment secondary to head injury, even without blood loss.

It is relatively uncommon for children to develop shocked bowel and in one series 17 was present in approximately 2.2% of children who presented with complex polytrauma. The vascular manifestations are of IVC collapse (which may or may not have a halo of low density surrounding fluid) and a reduction in the calibre, with increased enhancement, of the abdominal aorta and mesenteric vessels. Visceral features vary and may show increased enhancement of the adrenal glands, bowel, pancreas and kidney, or conversely reduced enhancement of the liver, spleen, pancreas and kidneys.

And finally
Thankfully it is uncommon for children to present with complex polytrauma but CT is recommended as first line imaging for all potential abdominal injury. It is hoped that the recently published Royal College of Radiologists imaging protocols will help steer radiologists and radiographers in this complex area and standardise imaging nationally.

References
8. RCR press release on college position regarding radiation exposure from CT in children.
Lap belt or handle bar injuries
Abdominal wall ecchymosis
Abdominal tenderness in a conscious patient
Abdominal distension
Clinical evidence of persistent hypovolaemia; for example persistent unexplained tachycardia
Blood from the rectum or nasogastric tube

TABLE 1
Inclusion criteria for abdominal and pelvic CT – reproduced from the Paediatric Trauma Protocol guidelines, RCR 2014.

Figure 1
Hepatic laceration. Grade IV linear, branching laceration.

Figure 2
Left renal and partial splenic devascularisation, secondary to intimal vascular tears. The left kidney and posterior regions of the spleen are unenhanced.

Figure 3
Sagittal reconstruction of an unstable distraction injury of the lumbar spine.
**Figure 4**
Sagittal reconstruction of a complete renal transaction, with surrounding haemorrhage and urinoma.

**Figure 5**
Bowel injury, with extensive free fluid, which was due to non-accidental injury. A sub-hepatic haematoma – the fluid indents the anterior surface of the left lobe of the liver – and healing rib fracture (expanded left rib) may also be seen.