Computed tomography of blunt abdominal trauma in children
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ABSTRACT
Computed tomography (CT) plays a major role in diagnosis of blunt abdominal trauma of haemodynamically-stable children. The purpose of this article is to review the CT findings in children with hepatic, splenic, renal, adrenal, pancreatic, bowel, and mesentery injuries and in children with blunt abdominal trauma and active haemorrhage.

Keywords: abdominal injury, blunt injury, children, computed tomography, liver trauma

INTRODUCTION
The number of children with intraabdominal injuries from blunt trauma has been increasing yearly. The mechanisms are diverse: children may be injured in motor vehicle crashes, pedestrian accidents, falls while playing, and by physical abuse. Rapid diagnosis is essential, as there is substantial morbidity and mortality if treatment is delayed, particularly in children with gastrointestinal perforation. Physical examination findings may not be reliable. Diagnostic peritoneal lavage (DPL) detects intraabdominal injury that results in haemoperitoneum, but it is rarely performed in children. DPL has been shown to be overly sensitive in children with trauma and does not provide information about the injured organ and the grade of injury; these are key information for nonsurgical management. A positive DPL has been associated with a negative laparotomy rate as high as 85% in children. However, DPL is useful for a child with severe head injury requiring an emergency neurosurgical procedure, during which DPL can be performed.

Nonsurgical management of haemodynamically-stable patients with solid organ injuries remains the standard treatment. Angiography and embolisation can be used for higher-grade injuries. For haemodynamically-stable children, ultrasonography (US) or abdominal computed tomography (CT) is used. US is rapid, noninvasive, inexpensive, and radiation-free. It detects both free intraperitoneal fluid and solid organ injuries. It has been reported as having a sensitivity of 55%–92.5% and a negative predictive value of 50%–97%, and has a consistently good specificity of 83%–100%. It has been proposed that US should be used solely as a screening tool to detect free fluid, and that a positive US finding necessitates prompt evaluation by CT to demonstrate injuries in the haemodynamically-stable patient. On the other hand, CT detects abdominal injuries accurately and is noninvasive, but it is relatively expensive and requires radiation exposure and injection of a contrast material.

In this article, all the CTs were done using a 16-slice CT scanner. The parameters, such as peak kilovoltage, tube current, section thickness, and pitch, were adjusted according to children’s body weight to comply with the ALARA (as low as reasonably achievable) principle. Abdominal CTs were done, with the scans starting from the diaphragm to the pubic symphysis. A nonionic contrast material was used at a dosage of 300 mg of iodine per ml, and was injected intravenously at a dosage of 2 ml/kg. Diluted contrast material were given orally or via nasogastric tube when the children were suspected to have sustained gastrointestinal tract injury. Obtaining as much information as possible about a child’s past medical history is always worthwhile. Several reports in the literature cite the risk of delayed splenic rupture and massive bleeding from minor abdominal trauma (Fig. 1) in haemophiliac children.
In children with abdominal trauma and are not hypotensive, the most useful laboratory tests to screen for intraabdominal injury include a complete blood count, liver function tests, and urine examination.\(^6\) Aspartate aminotransferase (AST) greater than 400 IU/L or alanine aminotransferase (ALT) greater than 250 IU/L, is predictive of hepatic injury.\(^3\) The liver is the most commonly injured abdominal organ in children, followed by the spleen. This article also discusses injuries to the kidney, pancreas, adrenal, bowel and mesentery. The grading system used in this article was taken from guidelines set by The American Association for the Surgery of Trauma.\(^7\)

**Hepatic trauma**

Most hepatic injuries occur in the posterior segment of the right lobe.\(^8\) The major CT features of blunt liver trauma are lacerations, subcapsular and parenchymal haematomas, active haemorrhage, and juxtahepatic venous injuries. Minor CT features include periportal low attenuation and a flat inferior vena cava (IVC).\(^9\) Hepatic lacerations appear as irregular linear or branching low-attenuation areas on enhanced CT. Lacerations that extend to the posterosuperior region of segment VII, the bare area of the liver, may be associated with retroperitoneal haematomas around the IVC and may be accompanied by right adrenal haematoma\(^9\) (Fig. 2). Subcapsular haematoma appears as an elliptic collection of low-attenuation blood between the liver capsule and liver parenchyma on enhanced CT. It flattens the liver (Fig. 3). Parenchymal haematomas or contusions are characterised by focal low-attenuation areas with poorly-defined irregular margins in the liver parenchyma on enhanced CT. Acute haematomas are typically hyperattenuated (40–60 HU) relative to normal liver parenchyma on unenhanced CT.\(^9\)

Active haemorrhage following blunt liver trauma is usually seen on early phase enhanced CT as focal high-attenuation areas that represent a collection of extravasated contrast material from arterial bleeding (Fig. 4). Willmann et al reported that the attenuation of active arterial extravasation on multidetector CT ranged from 91 to 274 HU (mean 155 HU), whereas that of clotted blood ranged from 28 to 82 HU (mean 54 HU).\(^10\)
Leakage of bile from a hepatic laceration is quite common, but in most cases, it is limited and transient, with no adverse sequelae. Significant injury to an intrahepatic or extrahepatic bile duct that requires definite treatment is relatively rare. On CT, bile duct injuries may appear as liver lacerations, ascites, or focal perihepatic fluid collections. However, hepatobiliary scintigraphy is often required to show actively extravasating bile at the site of duct disruption.

**Splenic trauma**

Splenic trauma should be suspected in children with left upper quadrant tenderness on palpation, left lower rib fractures, or evidence of left lower chest/abdominal contusion. The majority of splenic injuries are treated nonsurgically because of the risk of sepsis in the

**Fig. 6** Splenic laceration (grade II splenic injury). Axial enhanced CT image shows a hypoattenuated line (arrow) in spleen.

**Fig. 7** Splenic fracture (grade IV splenic injury). Axial enhanced CT image shows a fractured spleen (black arrows) and haemoperitoneum (H) adjacent to spleen. Note haematoma (white arrow) in left adrenal gland.

**Fig. 8** Normal spleen. Axial enhanced CT image taken early after bolus injection of contrast material shows diffuse heterogeneous enhancement of spleen (S).

**Fig. 9** Normal spleen. Axial enhanced CT image shows a splenic cleft (arrow).
postsplenectomy patient. There are varying degrees of splenic injury, which include lacerations, fractures, rupture, and intrasplenic and subcapsular haematomas. The finding on enhanced CT most often requiring surgery is active extravasation of intravenously administered contrast material from the region of splenic injury (Fig. 5).

Splenic laceration is seen on CT as an irregular, low-attenuation defect traversing the splenic parenchyma and capsule (Fig. 6). If the lesion extends through two capsular surfaces, it is called a fracture (Fig. 7). Laceration is associated with free intraperitoneal fluid. Intrasplenic haematoma appears as a well-defined lesion with decreased attenuation relative to normal splenic tissue on enhanced CT. A subcapsular haematoma also has low attenuation, but it is lentiform and flattens the spleen subjacent to the capsule. Pitfalls that may result in false-positive diagnosis of splenic injury include heterogeneous enhancement early after bolus injection of contrast material (Fig. 8) and splenic lobulations and clefts (Fig. 9) that may mimic a laceration. Splenic clefts and lobulations typically have smooth contours, whereas lacerations have irregular contours.

Renal trauma

The kidney is often injured in blunt abdominal trauma in children. If there is a combination of significant flank/abdominal trauma and haematuria, then CT should be used to evaluate renal injury. Asymptomatic haematuria with fewer than 50 red blood cells/high power field, in the absence of shock, is a low-yield indication for abdominal CT in children with blunt abdominal trauma. Renal contusions are characterised by focal areas of decreased enhancement in the renal parenchyma (Fig. 10). They may have sharply- or poorly-defined margins. Subcapsular haematomas appear as crescentic lesions compressing adjacent renal parenchyma (Fig. 11).

Renal lacerations appear as linear, low-attenuation areas in the parenchyma (Fig. 12). They generally contain clotted blood and therefore do not enhance. Perirenal haematomas are common and may be large. If there is contrast enhancement within a laceration or around the kidney during the pyelographic phase of the CT examination, this indicates a urine leak (Fig. 13). Excretory-phase enhanced CT of the kidneys performed three or more minutes after administration of contrast material is necessary for complete assessment of a suspected renal injury, so that a collecting system injury will not be overlooked.

A kidney with a preexisting abnormality is at an increased risk of injury. Trauma to an abnormal kidney occurs more frequently in children than in adults. Such injuries include disruption of the renal pelvis or ureteropelvic junction in patients with hydronephrosis (Fig. 14) or an extrarenal pelvis, intracystic haemorrhage or rupture of a renal cyst, laceration of ectopic or horseshoe kidneys, and laceration of fragile, infected kidneys.

Adrenal trauma

Posttraumatic adrenal haematoma in children is uncommon. It is usually unilateral and right-sided, and associated ipsilateral injury is often present. On CT, the
haematoma is oval or triangular (Fig. 15). Disruption of the adrenal limbs and blood throughout the perirenal space may be noted.\(^{(8)}\)

**Pancreatic trauma**

Pancreatic injury is rare, compared with other solid organ injury in children; however, injury from falls onto the handlebar of a bicycle, that crushes the upper abdomen, is a mechanism that is very likely to cause pancreatic injury.\(^{(6)}\) Diagnosing traumatic pancreatic damage is difficult. The clinical symptoms of abdominal pain, nausea, vomiting, and fever are not very specific to pancreatic injury. Furthermore, these symptoms do not correlate well with the severity of the damage.\(^{(16)}\) The pancreas can be crushed in blunt trauma if it impacts against an adjacent vertebral column. Two-thirds of pancreatic injuries occur in the
pancreatic body; the remainder occurs equally in the head, neck, and tail. Associated injuries, especially to the liver, stomach, duodenum, and spleen, occur in over 90% of cases. (11)

Direct signs of pancreatic injury on CT include pancreatic laceration, transection (Fig. 16), and comminution. Fluid collections, such as haematomas, pseudocysts, and abscesses, are often seen communicating with the pancreas at the site of fracture or transection. Focal enlargement of the pancreas (Fig. 17) and peripancreatic fluid suggest pancreatic injury. Peripancreatic fat stranding, haemorrhage, and fluid between the splenic vein and pancreas are useful secondary signs. (11)

**Bowel and mesentry trauma**

The CT findings of the bowel, or mesenteric injury are bowel discontinuity, extraluminal oral contrast material (Fig. 18), extraluminal air (Figs. 19 & 20), intramural air,
bowl-wall thickening (Fig. 21), bowel-wall enhancement, mesenteric infiltration, and unexplained intraperitoneal and retroperitoneal fluid.(17) In children, bowel-wall enhancement without perforation has been reported as part of the hypoperfusion complex (shock bowel).(18) Mesenteric infiltration (stranding) can be associated with mesenteric injury (Fig. 22), with or without bowel perforation, but bowel-wall thickening associated with stranding is highly suggestive of significant bowel injury.(17) Haematomas contained within the wall of the gastrointestinal tract (intramural haematomas) are most commonly duodenal but can occur elsewhere in the small intestine or, less commonly, in the stomach or colon.(19) The injury can usually be managed nonoperatively. Large duodenal haematomas can result in proximal small bowel obstruction. The CT appearance is that of focal bowel wall thickening(10) (Fig. 23).

CONCLUSION
CT is helpful in demonstrating injuries to abdominal organs. However, clinical information and close monitoring of children after blunt abdominal trauma are the most important for treatment of these children.

REFERENCES
Question 1. Concerning children with blunt abdominal trauma:
(a) For haemodynamically-stable children, ultrasonography is used. ☐ ☐
(b) Ultrasonography detects free fluid. ☐ ☐
(c) Ultrasonography cannot detect solid organ injuries. ☐ ☐
(d) Angiography and embolisation can be used for high-grade injuries. ☐ ☐

Question 2. Concerning laboratory tests to screen for intraabdominal injury:
(a) A complete blood count is useful. ☐ ☐
(b) Urine examination is useful. ☐ ☐
(c) AST greater than 250 IU/L is predictive of liver injury. ☐ ☐
(d) ALT greater than 250 IU/L is predictive of liver injury. ☐ ☐

Question 3. In children with splenic injuries:
(a) They may have left lower rib fractures. ☐ ☐
(b) Most of them are treated nonsurgically. ☐ ☐
(c) Splenic clefts may mimic a splenic laceration. ☐ ☐
(d) On CT, splenic lacerations typically have smooth contours. ☐ ☐

Question 4. In children with renal injuries:
(a) If there is significant flank trauma and haematuria, CT should be used. ☐ ☐
(b) On CT, renal contusions appear as focal areas of decreased enhancement. ☐ ☐
(c) On CT, contrast enhancement within a laceration during the pyelographic phase indicates a urine leak. ☐ ☐
(d) A kidney with a preexisting abnormality is at increased risk of injury. ☐ ☐

Question 5. The CT findings of bowel or mesenteric injury are:
(a) Bowel discontinuity. ☐ ☐
(b) Extraluminal oral contrast material. ☐ ☐
(c) Bowel-wall thickening. ☐ ☐
(d) Unexplained intraperitoneal fluid. ☐ ☐

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