CME Article

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

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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.(1) 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.(2) 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.(3)

Nonsurgical management of haemodynamically-stable patients with solid organ injuries remains the standard treatment. Angiography and embolisation can be used for higher-grade injuries.(4) 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%.(5) 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.(5) 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.(2)

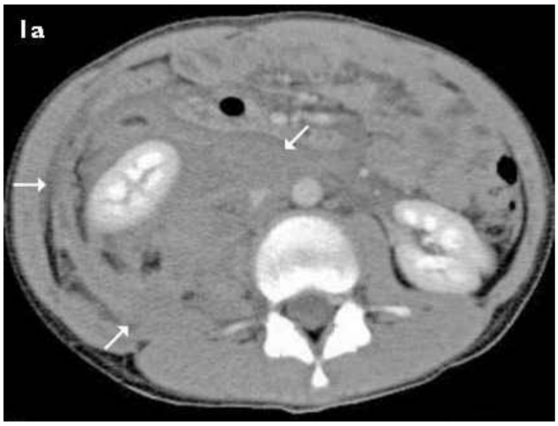

Fig. 1 An 11-year-old haemophiliac boy fell onto a table. (a) Axial enhanced CT image shows massive retroperitoneal haemorrhage (arrows). Right kidney is displaced anterolaterally. (b) Enhanced CT image shows extension of haemorrhage into the pelvic cavity. B: urinary bladder; R: rectum

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 (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.(6)

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Fig. 2 Hepatic laceration (grade IV liver injury). Axial enhanced CT image shows irregular branching low-attenuation areas in segment VII with blood around IVC (C) and right adrenal gland (arrow). Note small amount of air (black arrow) in the abdominal wall adjacent to a right rib.

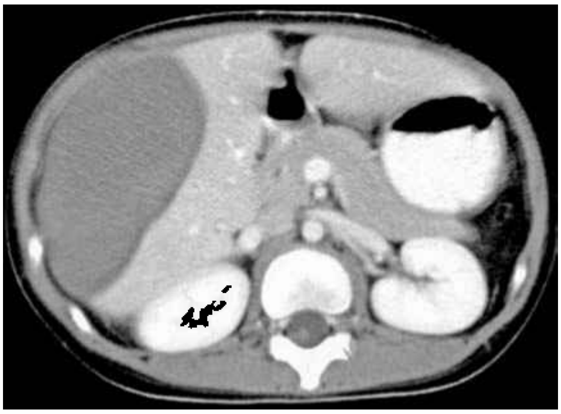

Fig. 3 Subcapsular haematoma of the liver (grade II liver injury). Axial enhanced CT image shows elliptic collection of low-attenuation blood between capsule and parenchyma.

Fig. 4 Liver laceration with active haemorrhage (grade IV liver injury). Axial enhanced CT image shows laceration of segment 4A with extravasation of contrast material from active haemorrhage (white arrows). Note intraparenchymal haematoma (black arrow) and haemoperitoneum.

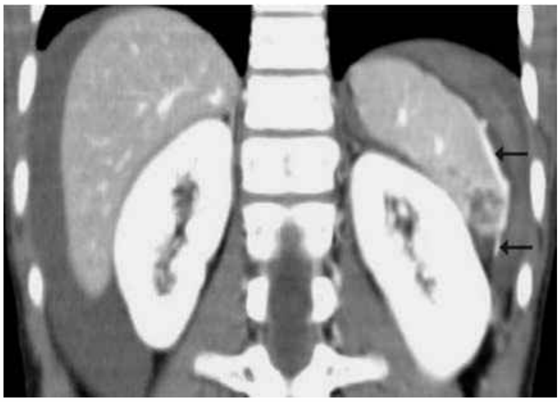

Fig. 5 Coronal reformatted enhanced CT image (grade III splenic injury) shows haematomas in lower portion of spleen with leakage of contrast material (arrows) from active haemorrhage.

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]

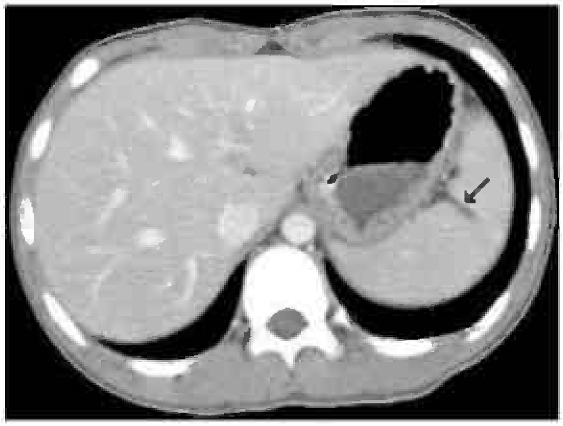

Fig. 6 Splenic laceration (grade II splenic injury). Axial enhanced CT image shows a hypoattenuated line (arrow) in spleen.

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.

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.[9] 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.[11]

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.[6] The majority of splenic injuries are treated nonsurgically because of the risk of sepsis in the

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).

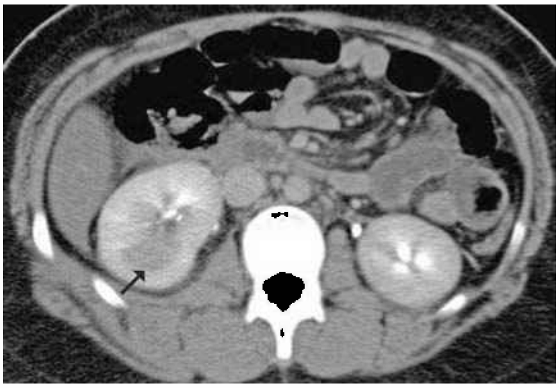

Fig. 10 Right renal contusion (grade I renal injury). Axial enhanced CT image shows a focal area of decreased enhancement (arrow) in the right kidney.

Fig. 11 Subcapsular haematoma of the right kidney (grade I renal injury). Axial enhanced CT image shows the acute subcapsular haematoma as a crescentic lesion (H) compressing the adjacent renal parenchyma. Note blood in the right pararenal space (arrows).

Fig. 12 Deep laceration of the right kidney with large perirenal haematoma (grade IV renal injury). Axial enhanced CT image shows multiple lacerations of the right kidney, perirenal haematoma (arrows), and haemoperitoneum.

postsplenectomy patient.[12] 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[12] (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.[12] 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.[8]

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.[6] 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.[13] Renal contusions are characterised by focal areas of decreased enhancement in the renal parenchyma (Fig. 10). They may have sharply- or poorly-defined margins.[14] 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[14,15] (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.[14]

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.[14]

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

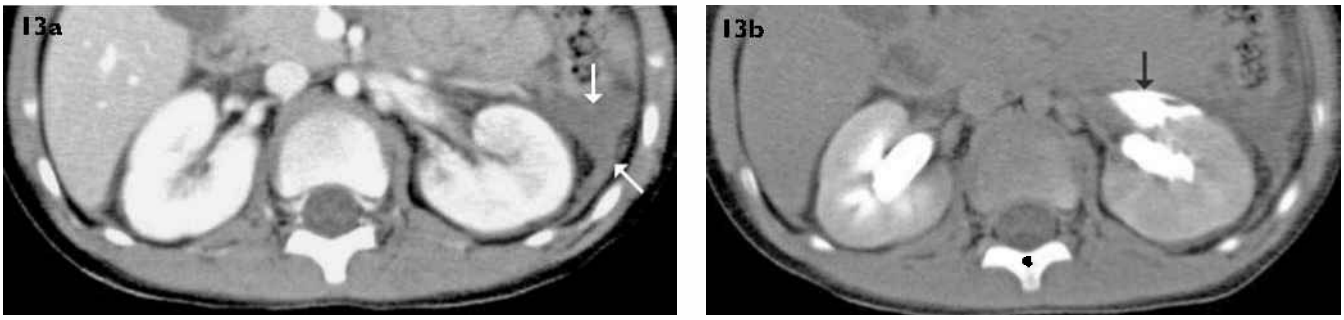

Fig. 13 Ruptured collecting system of the left kidney (grade IV renal injury). (a) Axial enhanced CT image shows blood in the left pararenal space (arrows). (b) Axial enhanced CT image taken seven minutes later shows leakage of contrast material (arrow) anterior to the left kidney. There is also a slightly enlarged and abnormally enhanced left kidney.

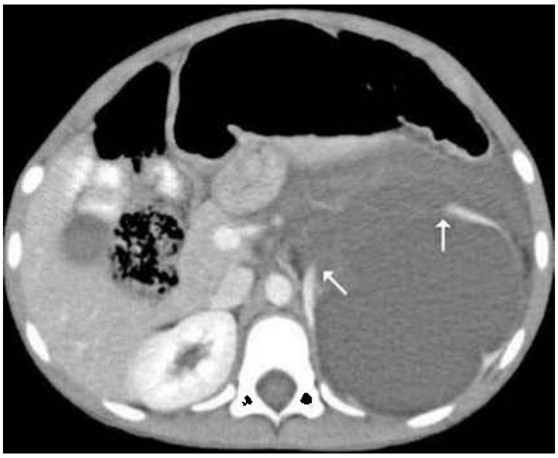

Fig. 14 Ruptured left kidney with hydronephrosis from ureteropelvic junction obstruction. Axial enhanced CT image of a six-year-old boy who fell down on his anterior abdomen shows rupture of the anterior portion (arrows) of the left kidney with severe hydronephrosis. Note fluid, probably a combination of urine and blood, anterior to left kidney.

Fig. 15 Right adrenal haematoma (grade V adrenal injury). Axial enhanced CT image shows an oval-shaped hypoattenuated mass (arrow) in the right adrenal gland.

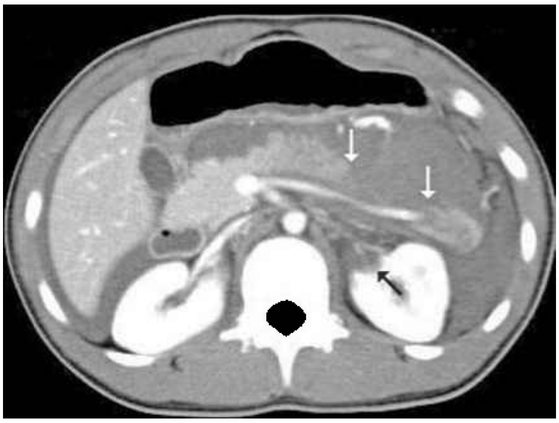

Fig. 16 Pancreatic transection (grade III pancreatic injury). Axial enhanced CT image shows disruption of the body of the pancreas (white arrows), heterogeneous attenuation of body and tail of pancreas, large amount of haemoperitoneum around the pancreas and liver, active haemorrhage posterior to the stomach, and haematoma in the left kidney (black arrow).

Fig. 17 Pancreatic contusion (grade II pancreatic injury). Axial enhanced CT image shows an enlarged body of pancreas with heterogeneous attenuation (arrows).

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

Fig. 18 Jejunal tear. Axial CT image shows leakage of oral contrast material (white arrows) into the pelvic cavity. Note a small pneumoperitoneum (black arrow).

Fig. 19 Pneumoperitoneum from jejunal perforation. Axial enhanced CT image shows free air anterior to the liver (black arrows) and around the ligamentum teres (white arrows).

Fig. 20 Perforation of the second portion of the duodenum (grade IV duodenum injury). Axial enhanced CT image shows thickened walls of the second portion of the duodenum (black arrow), right retroperitoneal fluid, and right retroperitoneal air (white arrow).

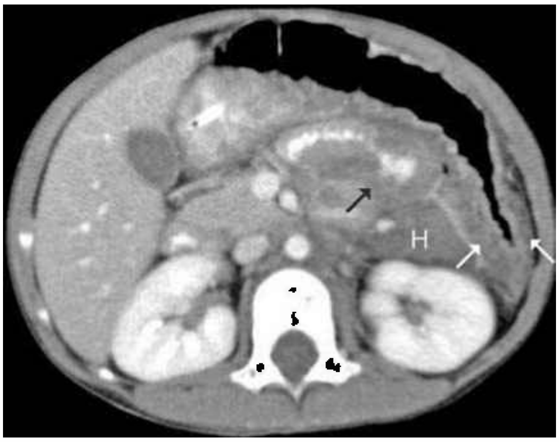

Fig. 21 Jejunal perforation (grade III small bowel injury). Axial enhanced CT image shows a thickened wall of proximal jejunum (black arrow). Note haemoperitoneum (H) and thickened walls of the distal transverse colon (white arrows).

Fig. 22 Tear of mesentery and contusion of distal ileum (grade I small bowel injury). Axial enhanced CT image shows increased attenuation of mesenteric fat (M) in the right lower abdomen and thickened wall of the distal ileum (arrows).

Fig. 23 Duodenal haematoma. Axial enhanced CT image shows thickening of the lateral wall of the descending portion of the duodenum with hypoattenuation (arrow).

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 mesentery 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, bowel-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[8] (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

1. Oztürk H, Onen A, Otçu S, et al. Diagnostic delay increases morbidity in children with gastrointestinal perforation from blunt abdominal trauma. Surg Today 2003; 33:178-82.
2. Richards JR, Knopf NA, Wang L, McGahan JP. Blunt abdominal trauma in children: evaluation with emergency US. Radiology 2002; 222:749-54.
3. Potoka DA, Saladino RA. Blunt abdominal trauma in the pediatric patient. Clin Ped Emerg Med 2005; 6:23-31.
4. Garcia VF, Brown RL. Pediatric trauma: beyond the brain. Crit Care Clin 2003; 19:551-61.
5. Eppich WJ, Zonfrillo MR. Emergency department evaluation and management of blunt abdominal trauma in children. Curr Opin Pediatr 2007; 19:265-9.
6. Wegner S, Colletti JE, Van Wie D. Pediatric blunt abdominal trauma. Pediatr Clin North Am 2006; 53:243-56.
7. AAST injury scaling and scoring system. In: The American Association for the Surgery of Trauma [online]. Available at: www.aast.org/Library/dynamic.aspx?id=1322. Accessed July 31, 2007.
8. Sivit CJ, Frazier AA, Eichelberger MR. Computed tomography of pediatric blunt abdominal trauma. Emerg Radiol 1997; 4:150-66.
9. Yoon W, Jeong YY, Kim JK, et al. CT in blunt liver trauma. Radiographics 2005; 25:87-104.
10. Willmann JK, Roos JE, Platz A, et al. Multidetector CT: detection of active hemorrhage in patients with blunt abdominal trauma. Am J Roentgenol 2002; 179:437-44.
11. Gupta A, Stuhlfaut JW, Fleming KW, Lucey BC, Soto JA. Blunt trauma of the pancreas and biliary tract: a multimodality imaging approach to diagnosis. Radiographics 2004; 24:1381-95.
12. Paterson A, Frush DP, Donnelly LF, et al. A pattern-oriented approach to splenic imaging in infants and children. Radiographics 1999; 19:1465-85.
13. Stalker HP, Kaufman RA, Stedje K. The significance of hematuria in children after blunt abdominal trauma. Am J Roentgenol 1990; 154:569-71.
14. Kawashima A, Sandler CM, Corl FM, et al. Imaging of renal trauma: a comprehensive review. Radiographics 2001; 21:557-74.
15. Smith JK, Kenney PJ. Imaging of renal trauma. Radiol Clin North Am 2003; 41:1019-35.
16. Bosboom D, Braam AW, Blickman JG, Wijnen RM. The role of imaging studies in pancreatic injury due to blunt abdominal trauma in children. Eur J Radiol 2006; 59:3-7.
17. Brody JM, Leighton DB, Murphy BL, et al. CT of blunt trauma bowel and mesenteric injury: typical findings and pitfalls in diagnosis. Radiographics 2000; 20:1525-36.
18. Taylor GA, Fallat ME, Eichelberger MR. Hypovolemic shock in children: abdominal CT manifestations. Radiology 1987; 164:479-81.
19. Strouse PJ, Close BJ, Marshall KW, Cywes R. CT of bowel and mesenteric trauma in children. Radiographics 1999; 19:1237-50.

SINGAPORE MEDICAL COUNCIL CATEGORY 3B CME PROGRAMME
Multiple Choice Questions (Code SMJ 200804B)

	True	False
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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(1) Answers will be published in the SMJ June 2008 issue. (2) The MCR numbers of successful candidates will be posted online at **www.sma.org.sg/cme/smj** by 15 June 2008. (3) All online submissions will receive an automatic email acknowledgment. (4) Passing mark is 60%. No mark will be deducted for incorrect answers. (5) The SMJ editorial office will submit the list of successful candidates to the Singapore Medical Council.

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