Imaging of Blunt Abdominal Trauma

A. Luana Stanescu, MD, Joel A. Gross, MD, Michelle Bittle, MD, and F.A. Mann, MD

Isolated blunt abdominal trauma (BAT) represents about 5% of annual trauma mortality from blunt trauma. As part of multiple-site injury (polytrauma), BAT contributes another 15% of trauma mortality. Exsanguination accounts for 80 to 90% of acute deaths from abdominal injury. More than 75% of such cases are amenable to surgery, and recent years have seen safe extension of nonoperative, image-guided treatments to most victims of blunt-force trauma. Early recognition and treatment decisions have been greatly impacted by increasingly sophisticated cross-sectional imaging and image-guided, minimally invasive therapies.

Blunt Disruptions of the Diaphragm, Abdominal Wall, and Flank

The diagnosis of diaphragm rupture is often missed. A high index of suspicion for diaphragmatic ruptures is warranted in appropriate clinical circumstances, such as lateral impact vehicle crashes, especially when left-sided, and direct frontal impacts. Classical findings are present in less than 40% of left-sided and less than 15% of right-sided diaphragm ruptures. Diagnostic peritoneal lavage (DPL) is falsely negative in 10 to 15% of cases. Delayed diagnoses are not uncommon: 10 to 15% of cases present with more than 24 hours delay, especially if the commonly associated intrathoracic (~90%) and intraabdominal (~60%) injuries require endotracheal intubation and positive-pressure ventilation. It is believed that the positive intrathoracic pressure prevents or limits herniation of abdominal contents through the diaphragm. New, unilateral “elevation” of hemidiaphragm following extubation may represent herniation of abdominal contents through a previously unrecognized diaphragm rupture.

Conventional radiography (chest radiographs with enteral tube placement; fluoroscopy) is abnormal in 60 to 90% of acute traumatic diaphragmatic ruptures, but most findings are nonspecific and cannot be distinguished from hemothrax, atelectasis, etc. Sensitivity is 46% in detecting left-sided diaphragm ruptures and only 17% for right-sided ruptures. There are two classical chest radiographic findings described for diaphragmatic rupture: intrathoracical herniation of a hollow viscus, with or without a collar sign (narrowed waist of a herniated intraabdominal organ due to compression as it squeezes through the diaphragmatic rupture), and detection of a nasogastric tube above the left hemidiaphragm.

In case series reports, diagnostic accuracy of computed tomography (CT) was equivalent, but not clearly superior, to conventional radiographic techniques. Thin-cut CT with multiplanar reformations is expected to improve sensitivity. At CT, the so-called “dependent viscera” sign (intraabdominal contents abutting the posterior thoracic wall, especially where the scan level is in the upper third of the liver or spleen) and the “collar” sign are nearly 100% specific. Other findings, such as the “discontinuous” and thickened diaphragm signs, show intermediate sensitivity and specificity (40 to 75%). Among reported series in which magnetic resonance imaging (MRI) depicted no diaphragmatic disruptions, no delayed diagnoses have been reported.

Injuries to the muscles and fascia surrounding the peritoneum may result in three types of injuries: the most common are type I, small defects, usually located in the lower abdominal wall secondary to bicycle handlebar blunt trauma. Type II includes larger abdominal wall defects after high-energy injuries like motor vehicle accident (MVA) or a fall from height, while type III are associated with intraabdominal herniations in the retroperitoneum following deceleration injuries. Contained hematomas also occur and do not typically require intervention, but may require embolization for expanding hematomas. High-energy abdominal wall hernias, open or closed, almost always require surgical intervention.

Injuries to the Solid Intraperitoneal Organs

Hemodynamic instability and evidence of on-going blood loss are the strongest indicators for the need of intervention in spleen and liver injuries. Among hemodynamically unstable patients that are not taken immediately to the operating suite, focused abdominal sonography for trauma (FAST) and DPL are diagnostically equivalent in detecting...
surgically important intraperitoneal hemorrhage due to solid organ injury (ie, selecting patients in whom laparotomy is therapeutic).64

Among hemodynamically stable patients, adjunctive diagnostic tests and serial physical examinations support nonoperative management.65-72 CT shows sensitivity in the mid to high 90% in the detection of surgically important injuries of the liver (Fig. 1) and spleen (Fig. 2).73,74

Although useful for epidemiologic studies, CT grading of liver and spleen injuries based on morphology of wounds does not reliably predict the specific outcome in individual cases.66,75-77 On the other hand, active hemorrhage shown by CT (Fig. 3) commonly leads to endovascular or surgical interventions whether bleeding is “focal” (intraparenchymal: pseudoaneurysms versus arteriovenous fistula), “diffuse” (free-flowing intraperitoneal fluid), or multifocal (most commonly seen in pelvic retroperitoneum in patients sustaining pelvic ring disruptions).10,78-84

Extravasated contrast appears as relatively discrete contrast collections that increase or “pool” on delayed imaging and measures within 10 to 20 HU of density of an adjacent major artery or aorta, during the vascular phase of imaging.

With current generation CT scanners, contrast-enhanced CT does not reliably distinguish between pseudoaneurysm (>70% believed to progress to rupture in adults) and AV fistula (natural history is uncertain).28,84-86 Parenchymal vascular lesions more often resolve spontaneously in children, and expectant observation may be

---

**Figure 1** A 42-year-old female sustained a grade IV liver laceration in a fall from a building. (A) Contrast-enhanced axial CT scan through the liver at the level of portal vein shows deep lacerations involving the dome of the liver and extending to the portal veins and IVC. (B) Contrast-enhanced axial CT scan shows small thrombus in IVC (arrow) and perihepatic hematoma. No evidence of active vascular extravasation.

**Figure 2** A 60-year-old male status post fall from ladder. (A, B) Contrast-enhanced CT scan through the dome of the liver (A) and at the level of splenic vein (B) demonstrates extensive lacerations of spleen. Fluid is present around both the liver and the spleen, but the fluid around the spleen is denser, indicating sentinel clot (arrow). More than 1 liter of hemoperitoneum was found at surgery.
preferable to urgent intervention. Notably, larger proportions of blunt trauma patients show extravasation when multidetector CT is used with higher injection rates (>2.5 ml/s) of intravenous contrast and scanning in early to mid portal venous phases.

Patients in whom CT detects multiorgan “package” injuries (eg, spleen and left kidney; left lobe of the liver; and pancreas) are more likely to undergo surgical intervention. In addition, liver lacerations that involve the hilum, particularly those associated with partial avulsion of the gall bladder, may benefit from repeated CT scanning or ultrasound, cholescintigraphy, or direct cholangiography to detect possible biliary complications.

Liver lacerations involving the hepatic veins, especially when associated with large regions (>10 cm) of focal hypoperfusion, are associated with injuries to the retrohepatic vena cava that commonly require intervention.

During postinjury monitoring, serial CT scans do not appear to be useful in altering therapy or determining the time for return to full activities for patients without increasing abdominal pain, falling hematocrit, or clinical features of intraabdominal sepsis. Nonetheless, if serial follow-up imaging is believed to be indicated in specific cases, ultrasound is a more cost-effective alternative than CT.

**Blunt Injuries to Retroperitoneum: Duodenum and Pancreas, Adrenals; Kidneys and Ureters; and Great Vessels**

Retroperitoneal injuries are sometimes suspected based on clinical history, physical examination findings, and laboratory tests (eg, microscopic hematuria) but often are occult. CT is the diagnostic procedure of choice, as neither FAST nor DPL adequately assess the retroperitoneum.

Conventional radiographic procedures (upper gastrointestinal positive-contrast fluoroscopy, intravenous, or retrograde pyelography) may be helpful in secondary or follow-up evaluations of individuals known to have sustained injuries to the duodenum and upper urinary tracts, respectively.

In adults, the duodenum and pancreas are rarely injured in isolation. However, children and adolescents may sustain isolated duodenal, or duodenal and pancreatic injuries, especially from bicycle handlebar goring mechanisms.

Pancreatic injuries range from contusions to lacerations, fractures, and duodenal-pancreatic disjunctions. The majority (>50%) of pancreatic injuries are contusions, hematomas, or superficial capsular lacerations. An additional 20 to 25% represent deeper pancreatic parenchymal lacerations. Direct signs include a fracture plane traversing the neck, body, or tail of the pancreas, or separation of the duodenum from the head of the pancreas.

The range of duodenal injuries includes contusion, mural hematoma, and lacerations (partial versus through-and-through). CT depiction of retroperitoneal fluid adjacent to the duodenum, especially when seen in conjunction with retroperitoneal gas, suggests duodenal injury.

Intravenous contrast-enhanced CT may also demonstrate asymmetric mural enhancement, and duodenal hematomas. Where intravenous contrast extravasation is shown, delayed images (5 to 30 minutes) facilitate distinction between medical and surgical bleeding (increased “pooling” of contrast on delayed images) and may facilitate the decision of whether and how to intervene.

CT contrast may be helpful in delineating both pancreatic and duodenal pathology. While controversy exists as to whether positive or negative alimentary (eg, water) contrast provides more diagnostic information, we favor water orally or per enteral tube. Although extraluminal positive enteral contrast can make a specific diagnosis of bowel rupture by CT, it is rare that this would be the only finding leading to surgical exploration, and positive contrast limits evaluation of wall and mucosal abnormalities (such as absent perfusion, which is better visualized with negative contrast agents).

Renal parenchymal injuries (Fig. 7), whether isolated or
combined with retro- and intraperitoneal injuries, are more common than duodenal or pancreatic injuries.\textsuperscript{140-142} Interventions are more often required when the collecting systems or ureters are injured, and when renal injuries are combined with pancreatic or bowel injuries.\textsuperscript{142} Even when FAST or DPL are “negative,” contrast-enhanced CT is indicated for gross hematuria (all age groups); children (<15 years old) with high levels of microscopic hematuria (>50 red blood cells per high-powered field, or 3+ or greater on urine dipstick), regardless of their hemodynamic status; and adults with he-

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image1.png}
\caption{A 7-year-old girl in high-speed MVC, front unrestrained passenger. (A) Initial contrast-enhanced axial CT scan shows deep liver lacerations extending to portal vein, porta hepatis, and gallbladder fossa. Spleen is poorly perfused, which can be a sign of hypovolemia. Large hemoperitoneum is present. (B) Initial contrast-enhanced axial CT scan shows that anterior gallbladder wall does not enhance (arrows). (C) Follow-up contrast-enhanced axial CT scan obtained 16 days later shows large biloma along inferior surface of left lobe of liver.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image2.png}
\caption{A 69-year-old female status post MVC. (A) Axial contrast-enhanced CT scan at the level of the pancreas shows active vascular extravasation (arrow) in the region of the portal triad. (B) Axial contrast-enhanced CT scan shows intraperitoneal accumulation of extravasated contrast inferiorly.}
\end{figure}
maturia (1+ or greater on urine dipstick, or >50+ red blood cells per high-powered field) who have any documented systolic hypotension (<90 mm Hg).140,143-148

Dynamic contrast-enhanced CT ideally shows clinically important renal vascular (vascular pedicle injuries including dissection, thrombosis, pseudoaneurysms, and AV fistulae), parenchymal (parenchymal lacerations), and collecting system injuries.109,142,149,150 When low- or iso-osmolar intravenous contrast agents are employed, imaging during late parenchymal phase and after a 5- to 10-minute delay detects the presence of virtually all important upper urinary tract injuries.151 Repeated CT scanning 24 to 72 hours after trauma aids in detection of complications among patients with high-grade renal injuries.152

Indirect intravenous contrast-enhanced CT findings of upper urinary tract injury include perinephric stranding and hematoma, and heterogenous parenchymal enhancement.153-156 Medial perinephric hematomas, especially when large and extending into the root of the mesentery, are associated with renal venous and uretero-pelvic junction (UPJ) injuries.144 Otherwise, the location and size of perinephric hematoma poorly correlates with the severity of injury.
of parenchymal injury or the need to intervene. However, large subcapsular hematomas can be associated with subsequent hypertension (Page kidney).\textsuperscript{157}

Direct intravenous contrast-enhanced CT findings of renal injury include parenchymal lacerations and vascular and/or urinary extravasations; the latter two necessitate intervention or follow-up imaging.\textsuperscript{144,156,158} The frequency, timing, and optimal methods for follow-up examination remain subjects of debate. Our practice is to perform a portal venous phase of the abdomen and pelvis, followed by 10-minute delayed images in patients with renal injuries or where unexplained fluid is found adjacent to the kidney, ureter, or bladder.

Bladder ruptures may be intra- or extraperitoneal, or a combination.\textsuperscript{159-163} Almost all extraperitoneal bladder ruptures (Fig. 8) are associated with high-energy osseous disruptions of the pelvic ring.\textsuperscript{162,164} Classical CT patterns of extraperitoneal extravasation are “molar tooth” configuration of contrast extravasation in the prevesical space (Fig. 8A); abdominal wall extension of the contrast (Fig. 8B); or, in cases with serious fascial plane disruptions, extension to scrotum, and/or thigh (Fig. 8C).

Although most intraperitoneal ruptures are also associated with high-energy osseous disruptions of the pelvis or acetabulum, an over-distended bladder rising out of the true pelvis may rupture from direct blunt-force impact without pelvic fracture.\textsuperscript{164} Contrast extravasation can be detected in paracolic gutters (Fig. 9A), inferior peritoneal recesses (rectovesical/rectouterine, vesicouterine) (Fig. 9B), or surrounding the liver edge (Fig. 9C).

With combined intra- and extraperitoneal bladder rupture, if one component is large and the other is small, contrast may exit only through the larger defect, leaving the other component undiscovered.

Hematuria associated with high-energy pelvic ring disruptions, especially if perivesical hematoma or bladder wall thickening is present, warrants positive-contrast cystography, which should not be considered adequate to exclude injury unless intravesical pressure reaches at least 40 cmH\textsubscript{2}O.\textsuperscript{162,163,165} Delayed images of the pelvis, with passive filling of the bladder by renal excretion of contrast, are not adequate to evaluate for bladder injury, as the extent of bladder filling and intravesical pressure cannot be controlled.
With the advent of CT, adrenal injuries are now recognized as the most common retroperitoneal injury.\textsuperscript{166,167} The right adrenal is injured much more often than the left, and bilateral adrenal hemorrhage is relatively rare.\textsuperscript{167,168} An association also exists between right adrenal hemorrhage and liver lacerations involving the bare area.\textsuperscript{169} Despite their frequency, adrenal hemorrhages very rarely require treatment. Embolization may be done for large, active extravasations associated with ongoing hemodynamic consequences.\textsuperscript{170,171}

Adrenocortical replacement therapy may be needed for hypoadrenalism, a very infrequent consequence of bilateral adrenal hemorrhage.\textsuperscript{172}

CT findings of adrenal injuries (Fig. 10) typically demonstrate irregular, globular enlargement of the gland, typically measuring 40 to 70 HU.\textsuperscript{173} However, definite distinction from preexisting nontraumatic adrenal pathology may require targeted follow-up CT, ultrasound, or MRI.\textsuperscript{174}

Figure 9  (A) A 25-year-old female in car versus pedestrian accident. Axial CT cystogram scan at the level of L2-L3 shows intraperitoneal contrast in right paracolic gutter and around small bowel loops. (B) A 33-year-old male in MCA. Axial CT cystogram scan at the level of acetabular roof identifies intraperitoneal contrast in rectovesical recess (long arrow) and the right and left anterolateral inferior peritoneal recesses (short arrow). (C) A 51-year-old male post forklift injury to the pelvis. Axial abdominal CT scan at the level of Morrison’s pouch following CT cystogram shows intraperitoneal contrast surrounding the liver edge.

Figure 10  A 63-year-old male in MCA. Axial IV enhanced CT chest scan shows new, bilateral adrenal hemorrhage.
**Blunt Injuries to Hollow Intraperitoneal Abdominal Viscera**

The small bowel sustains surgically important blunt injury more frequently than the colon. The spectrum of bowel injuries includes wall contusions, serosal injuries (“deserosalization”), perforations and transections, mesenteric rents, and hematomas. When mural disruption occurs in the proximal gastrointestinal tract (stomach through proximal jejunum), leakage of alimentary tract contents into the peritoneum induces acute chemical peritonitis and related clinical findings. Distal small bowel and colon spillage tend to present later as peritoneal sepsis. Delays in diagnosis of bowel injury are associated with complicated clinical courses and increased mortality. Serial physical evaluation of the abdomen alone (ie, without adjunctive diagnostic tests, such as CT, ultrasound or US, DPL) may be associated with >24-hour delay in diagnosis of surgically important bowel injuries in 10 to 15% of individuals with distracting injuries, such as femur fractures. DPL remains a somewhat more sensitive test than CT for isolated hollow viscus injury, even with intravenous and alimentary contrast enhancement, thin-sections, and multidetector technologies. However, less than 1% of surgically important blunt-force hollow visceral injuries occurring in adults are found in the absence of other, often more obvious and clinically immediate, intraabdominal injuries. Conventional radiography, ultrasound, and MRI have little or no role in the routine diagnosis of bowel injuries.

CT performed without oral or intravenous contrast enhancement may show intramural hematoma as focal, asymmetric hyperdensity within bowel wall with adjacent mesenteric edema (“misty mesentery”). Bowel contusion may be suggested on intravenous contrast-enhanced CT by focal or multifocal bowel thickening and mural enhancement. Oral contrast (positive or negative) may help in appreciation of intramural hematomas.

In contrast, diffuse bowel wall thickening and enhancement (Fig. 13), especially associated with slit-like infrahepatic inferior vena cava and hypodense and contracted spleen, suggests under-resuscitation and the so-called hypoperfusion or shock bowel syndrome. Spillage of positive alimentary contrast or contents and free intraabdominal gas are diagnostic of bowel perforation.

While use of oral positive contrast appears to be safe, its use does not seem to be diagnostically essential and may delay imaging in acutely ill patients. The combination of triangular interloop collections within the mesentery and abnormal-appearing bowel wall strongly suggests transmural bowel injury.

Likewise, nonphysiologic amounts of free intraperitoneal fluid (>75 mL in minimally resuscitated women of child-
bearing age, >25 mL in minimally resuscitated adult males, and >25 mL in children) without evidence for intraperitoneal solid organ injury suggests occult hollow viscus injury and should lead to additional diagnostic testing or serial examinations.\textsuperscript{179,197,198}

Acute abdominal compartment syndrome (ACS), a potentially treatable and often fatal complication of trauma, is a manifestation of shock-related capillary leak and is not uncommon among severely injured patients who have received vigorous fluid resuscitation.\textsuperscript{199} Although ACS may be seen in the absence of significant intraabdominal injury, hemodynamically significant major intraabdominal trauma is a common antecedent. Findings at intravenous contrast-enhanced CT include slit-like infrahepatic vena cava, marked diffuse edema and dense mural/mucosal staining of the bowel, flattening of the kidneys, expansion of the intraperitoneal space (circular cross-section of the abdomen at the level of the renal veins, elevation of the diaphragms that may invert to efface the left and right cardiac ventricles, distension of the common femoral veins, and bilateral inguinal “hernias”).\textsuperscript{200-203}

### Conclusions

Imaging modalities of choice in evaluating blunt trauma patients are CT and FAST. Intravenously contrast-enhanced CT remains the most common and efficacious means of correctly categorizing patients into those likely manageable with nonoperative techniques and those who need surgery. The increasing tendency of nonoperative management requires early identification of the lesions, which is provided by the increasing sophistication of the CT techniques. CT also provides a very important tool in following up the patients and detecting complications not initially diagnosed.

### Acknowledgments

We thank Dr Lee B. Talner for proofreading the manuscript and Dr Harigovinda R. Challa for case contributions.

### References

2. Gilroy D: Deaths from blunt trauma, after arrival at hospital: plus ca change, plus c’est la meme chose. Injury 36:47-50, 2005

### Injuries to the Abdominal Aorta and Its Main Tributaries, and the Vena Cava

Traumatic disruption of the midline great vessels is rare. Both clinically and at imaging, the presence of a midline hema-
toma surrounding the aorta and infrahepatic vena cava warrants careful attention. Aortic injuries are commonly associated with lapbelt injuries (thoracolumbar spine distraction injuries) and may present with an acute aortic syn-
drome.\textsuperscript{204-207} Infrahepatic vena cava injuries are suggested by surrounding pericalv or juxta caval hematoma, contour ir-
regularity, and indistinct contrast interface with irregular lu-
men margins or contrast-extravasation on contrast-enhanced CT.\textsuperscript{208,209}

---

**Figure 14** A 54-year-old in MVC crash. Axial contrast-enhanced abdominal CT scan at the level of lower abdomen shows abnormal thickening of the jejunum with triangular-shaped areas of mesenteric and interloop fluid (arrow).
120. Biggianti D, Boverie JH, Dondelinger RF. CT of blunt trauma of the pancreas in adults. Eur Radiol 9:244-249, 1999
incidence and organ distribution. AJR Am J Roentgenol 178:17-20, 2002


