Multidetector computed tomography (CT) represents a significant advance in CT technology and can allow the accurate assessment of trauma patients, including the detection of traumatic retroperitoneal injuries, many of which are clinically occult. Retroperitoneal injuries include duodenal, pancreatic, vascular, renal, and adrenal injuries. Abnormal blood, fluid, or air within the retroperitoneal spaces may be isolated findings but can also occur in association with these injuries, and their recognition is the key to correctly identifying the injury. Accurate characterization of injury with CT can affect clinical management and can help minimize unnecessary laparotomies. Equivocal findings at initial abdominal CT should prompt close clinical follow-up with possible imaging follow-up, particularly for suspected occult duodenal and pancreatic injuries.

Abbreviations: IVC = inferior vena cava, MPR = multiplanar reformatted

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Introduction
Blunt abdominal and pelvic trauma can cause significant and sometimes life-threatening injuries to retroperitoneal structures. Retroperitoneal injuries are known to occur in a significant minority of abdominal trauma cases (12% of hemodynamically stable patients evaluated at one center [1]). Physical examination and laboratory tests can be unreliable in detecting abdominal injuries, particularly retroperitoneal injuries (2). Bedside tests such as diagnostic peritoneal lavage and focused ultrasonography for the assessment of trauma can yield negative findings or fail to help detect signs of retroperitoneal injury, even in the presence of significant retroperitoneal injury, since these methods principally help assess the peritoneal space (3,4).

Imaging, particularly computed tomography (CT), plays a central role in the assessment of retroperitoneal structures following blunt trauma. Clinically significant imaging findings of retroperitoneal injury can be subtle initially and thus potentially overlooked unless specifically sought out on CT scans by the radiologist (4). Historically, conventional CT has demonstrated only limited sensitivity in identifying retroperitoneal injuries, particularly injuries of the pancreas. Only 68% of pancreatic injuries were detected with single-section helical CT in the setting of blunt abdominal trauma in a retrospective review of cases from 1996 to 2000 at a major level one trauma center (5). CT technology has improved significantly since then with the introduction of multidetector CT. This modality offers greater acquisition speed, improved spatial resolution, intravenously administered contrast material bolus timing, and reduced motion artifacts (2). Multidetector CT has recently been shown to have a high degree of accuracy in the setting of trauma, with a reported sensitivity approaching 100% for the identification of active bleeding as well as bowel, mesenteric, and pancreatic injuries in the initial assessment of blunt abdominal trauma in 252 patients at one center (2). At another center, multidetector CT had an overall sensitivity of 94%, specificity of 100%, and accuracy of 97% in the evaluation of high-energy trauma injuries in 153 patients (6).

Multidetector CT also plays an important role in the triage of trauma patients in the acute setting. Accurate radiologic characterization of injury can help in selecting patients who need urgent surgical intervention, as opposed to those in whom nonoperative management is possible, particularly since the morbidity rate for an unnecessary laparotomy (ie, completely negative findings or nontherapeutic results) in the setting of trauma is between 8.6% and 25.9%. Respiratory complications (atelectasis or pneumonia), prolonged paralytic ileus, surgical wound infection, and small bowel obstruction are the most common complications (7). The mean length of stay for patients with completely negative laparotomy findings is also considerably increased (average of 4.7 days at one center [4]).

In this article, we review the relevant anatomy of the retroperitoneum and describe imaging technique in the evaluation of retroperitoneal injuries, with multidetector CT as the primary imaging modality. In addition, we discuss and illustrate injuries to retroperitoneal structures (duodenal, pancreatic, adrenal, and vascular injuries) as well as abnormal posttraumatic findings within the retroperitoneum (hemorrhage, paraspinal or spinal injury, air, fluid). We also propose an algorithm for the diagnosis of traumatic retroperitoneal injuries. Imaging of renal and urinary tract injuries warrants more thorough consideration than can be covered here; indeed, reviews of these topics have recently appeared in this journal and elsewhere (8,9).

Relevant Anatomy
The retroperitoneum is that portion of the abdomen posterior to the peritoneal cavity from the diaphragm to the pelvic inlet. It is separated from the peritoneum anteriorly by the posterior peritoneal fascia and is bounded posteriorly by the transversalis fascia. It contains portions of the colon and duodenum as well as the pancreas, kidneys, adrenal glands, abdominal aorta, and inferior vena cava (IVC) (10). The retroperitoneum has traditionally been divided into the posterior pararenal space, containing only fat; the perirenal spaces, containing the kidneys, renal pelvis, proximal ureters, adrenal glands, and perirenal fat; and the anterior pararenal space, containing the retroperitoneal segments of the colon and duodenum, the pancreas, and the root of the small
bowel mesentery. The boundaries and contents of the retroperitoneal spaces are shown in Table 1. More recently, the classic tricompartment model has been modified to reflect the understanding that the fascia separating the spaces is laminar, variably fused, and potentially expandable as a result of embryologic partial fusion of the dorsal mesenteries. The retromesenteric, retrorenal, and lateroconal planes are potential routes of interfascial communication between the retroperitoneal spaces (Fig 1). Retroperitoneal hemorrhage or

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<tr>
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<td>Peritoneum, anterior perirenal fascia, latero-</td>
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<td>Posterior pararenal</td>
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<td>fascia over the psoas muscle continuous with the</td>
<td>[185x675] transversalis fascia</td>
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Figure 1. Fascial planes and spaces of the retroperitoneum. (a) Drawing illustrates the traditional tricompartment model of the retroperitoneum, which is accordingly divided into the anterior pararenal space (APS), perirenal space (PS), and posterior pararenal space (PPS). The anterior renal fascia (ARF), posterior renal fascia (PRF), and lateroconal fascia (LCF) divide the spaces. (b) Drawing illustrates the recently modified tricompartment model, which reflects the understanding that the perirenal fascia is laminar and variably fused and there are interfascial connections between the spaces. The retromesenteric plane (RMP), retrorenal space (RRS), and lateroconal space are potential interfascial communications. Perinephric septa run between the renal capsule and the perinephric fascia, allowing subcapsular fluid to communicate with the retrorenal space or retromesenteric plane. APS = anterior pararenal space, PPS = posterior pararenal space, PS = perirenal space (11,12).
rapidly expanding fluid collections can spread via these interfascial connections (11).

Below the kidneys, the retroperitoneal spaces are in reality a single space with direct contiguity between the anterior and posterior portions. Retroperitoneal hemorrhage or fluid can spread from the abdominal retroperitoneum into the extraperitoneal pelvis along the anterior and posterior perirenal fasciae, which combine to form the fascial plane in the iliac fossa (12). Superiorly, the perirenal fasciae are attached to the diaphragm. On the right side, the bare area of the liver is directly connected to the anterior pararenal space. Therefore, hepatic lacerations involving the bare area of the liver can be a source (albeit uncommon) of retroperitoneal hemorrhage (13).

**Imaging Technique**

Multidetector CT offers significantly faster scanning times and improved image resolution due to thinner collimation and reduced partial volume and motion artifacts compared with single-section helical CT. The improved coverage speed and z-axis resolution have made angiographic, multiplanar reformatted (MPR), maximum-intensity-projection, and volume-rendered images available for clinical application (14,15).

Depending on the available scanner, a typical protocol for multidetector CT of the abdomen and pelvis in the setting of trauma is as follows: 1–2.5-mm collimation; 1–1.75 pitch; and 100–150 mL (300–370 mg of iodine per milliliter) of contrast agent injected intravenously at 3–6 mL/sec (15). Scanning is performed beginning 60–70 seconds after the onset of contrast material injection in the portal venous phase from the diaphragm to the lesser trochanters. Images are reconstructed with a 2.5–3-mm thickness at 2–3-mm intervals. Coronal and sagittal reformatted images may be obtained and sent for soft-copy interpretation along with the axial images. Alternatively, the thin-section axial data can be reformatted on the interpreting workstation as needed depending on the picture archiving and communication system and workstation configuration in place. The use of oral contrast material is optional. It has been shown to be safe in trauma patients, with a number of studies showing an extremely low risk of aspiration (15). Typical agents include 500–600 mL of diluted (2%–5%) water-soluble oral contrast material administered orally or through a nasogastric tube as the patient is being stabilized or transported to the CT suite. Recent literature suggests that multidetector CT without oral contrast material may be adequate for the detection of bowel and mesenteric injuries and comparable to single–detector row helical CT with oral contrast material (16). If thoracic CT is also needed, thin-collimation scanning is performed through the thorax initially during the vascular phase for MPR images of the aorta, followed immediately by coverage of the abdomen and pelvis during the parenchymal phase with use of the same intravenous contrast material bolus (14). Selective use of delayed scanning (5–8-minute delay) may be helpful in cases of suspected intraabdominal bleeding or in the evaluation of urinary tract injuries when renal or severe pelvic injuries are identified (14).

**Injuries to Retroperitoneal Structures**

**Duodenal Injuries**

Although the deep, central, retroperitoneal location of most of the duodenum protects it against frequent injury, the morbidity and mortality rates for traumatic duodenal injuries remain high. Mortality rates for traumatic duodenal injury range from 6% to 25% (4). Complications including abscess, fistula, respiratory failure, and renal failure occur frequently (30%–60% of cases). The high complication rate is due in part to diagnostic delays and missed injuries, since surgical repair becomes more difficult if the injury is recognized late. If recognized early, up to
80% of duodenal injuries can be safely repaired primarily (4). Delayed diagnosis is often associated with a protracted, difficult clinical course, including the development of pseudocysts, fistulas, pancreatitis, sepsis, or organ failure (4,17). Time from injury to definitive treatment is an important factor in the development of late complications and mortality, with markedly increased morbidity and mortality rates when the diagnosis is delayed more than 24 hours (18). Fortunately, duodenal injuries are relatively uncommon. A 6-year statewide review in Pennsylvania found a prevalence of blunt duodenal injury of only 0.2% (206 of 103,864 trauma registry entries), with only 30 of these patients sustaining full-thickness duodenal injuries (19). A similar prevalence of blunt duodenal injury was observed in Texas over a 10-year period, during which time 35 cases (0.2%) were identified from data on 22,163 patients with blunt trauma (17).

Duodenal injuries range in severity from minor duodenal hematoma and partial-thickness lacerations to complex lacerations and even massive disruption of the duodenopancreatic complex (20). Traumatic duodenal perforation requires emergent surgical intervention, whereas duodenal hematoma is frequently managed conservatively. CT findings of duodenal injury can be subtle. In one study of the accuracy of CT in diagnosing duodenal or other small bowel injuries, only 10 of 17 injuries (59%) were prospectively (i.e., preoperatively) interpreted as suggestive of bowel injury, which increased to 88% (15 of 17 injuries) at retrospective evaluation (21). The authors concluded that CT is sensitive for the diagnosis of bowel rupture from blunt trauma but requires careful inspection of images and attention to technique for the detection of subtle findings (21).

CT findings of duodenal injury include duodenal wall thickening, periduodenal fluid, fluid in the right anterior pararenal space, diminished bowel wall enhancement of the injured segment, extraluminal air, extraluminal oral contrast material, and the “sentinel clot” sign (21–23). In addition to detecting injury, it is critical to identify signs supporting the presence (or absence) of perforation, since they will influence the management algorithm. Extraluminal air is a reliable sign of duodenal perforation and is highly predictive of such perforation in the absence of pneumothorax or prior diagnostic peritoneal lavage. In a small series of patients with duodenal injuries who had undergone CT at the time of admission, extraluminal air, extraluminal oral contrast material, or both were specific signs of duodenal perforation and were useful in differentiating duodenal perforation from hematoma (22). In a large trauma series examining small bowel perforation, the reported sensitivity and specificity of extraluminal air for traumatic perforation were 46% and 99%, respectively (24). It is sometimes difficult to distinguish a duodenal hematoma from duodenal perforation, since extraluminal air is not always present in cases of traumatic perforation (22,23). Extraluminal fluid in the absence of solid organ injury can be seen in both duodenal hematoma and perforation. A small fluid collection adjacent to the duodenum can be an indication of a sentinel clot and an indirect sign demonstrating the origin or site of the duodenal injury (23).

Extravasation of oral contrast material is specific for duodenal perforation; however, by itself it has limited sensitivity (only 19% in a retrospective analysis [24]). Furthermore, many institutions no longer use oral contrast material routinely for trauma imaging. As mentioned earlier, recent literature suggests that multidetector CT without oral contrast material is adequate for the detection of bowel and mesenteric injuries and is comparable to single-detector row helical CT with oral contrast material (16). Focal bowel wall thickening may be an indirect sign of duodenal injury in the setting of blunt trauma. Given the proximity of the duodenum to the pancreas, injuries to the duodenum are often associated with injuries to the pancreatic
thirds of blunt pancreatic injuries occur in the pancreatic body, with the remainder occurring with equal frequency in the head, neck, and tail. Complete pancreatic rupture as a result of trau-
matic transection usually occurs in the line of the superior mesenteric vein at the neck of the gland (26). Many pancreatic injuries are not apparent at initial clinical examination and may become apparent only when complications arise (4).

Mortality rates for pancreatic injuries range from 10% to 30% and have been reported as high as 60% when treatment is delayed (27).
The reported sensitivity and specificity of CT in the detection of pancreatic injury have been variable, since findings may initially be subtle or unapparent (10). Most of the existing literature on CT of pancreatic trauma deals with nonhelical or incremental CT, with a reported overall sensitivity of 80% for the detection of all grades of pancreatic injury (10,26). In a retrospective study of 50 patients with blunt pancreatic injury at one center, preoperative helical CT was found to be...
areas of hypoattenuation surrounded by normally enhancing pancreatic tissue (Fig 7). Lacerations appear as areas of linear hypoattenuation perpendicular to the long axis of the pancreas (Figs 8–10). Pancreatic transection is a full-thickness laceration that typically results in transection of the pancreatic duct (Figs 11, 12). Specific CT findings of pancreatic injury include fracture of pancreatic injuries include parenchymal contusions and lacerations that range in severity from minor to massive disruption of the gland. Pancreatic contusions appear at CT as focal or diffuse areas.
the pancreas, pancreatic laceration, focal or diffuse pancreatic enlargement or edema, pancreatic hematoma, and active bleeding or extravasation of intravenous contrast material (25). Fluid separating the splenic vein and the pancreas is highly suggestive of pancreatic injury (29,30). Normally, the splenic vein is closely apposed to the posterior aspect of the pancreas or is separated from the pancreas by a thin layer of fat. When fluid between the splenic vein and the pancreas is seen in the setting of abdominal trauma, a pancreatic injury should be suspected. In the study in which this finding was initially reported, it was observed in nine of 10 patients with surgically or autopsy-proved pancreatic injury (29). It can also be seen in patients with fluid in the anterior pararenal space without pancreatic injury (30) but is rarely the only abnormal CT finding in patients with blunt pancreatic trauma. Additional nonspecific CT signs of pancreatic injury include inflammatory changes in the peripancreatic fat and mesentery; fluid surrounding the superior mesenteric artery; thickening of the left anterior renal fascia; pancreatic ductal dilatation; acute pseudocyst formation or a peripancreatic fluid collection; fluid in the anterior and posterior pararenal spaces; fluid in the transverse mesocolon and lesser sac; hemorrhage into the peripancreatic fat, mesocolon, and mesentery; extraperitoneal fluid; and intraperitoneal fluid (25,29).

Besides helping detect injury, imaging can help distinguish injuries that require surgical management from those that can be managed conservatively. Key to this determination is the integrity of the pancreatic duct. Pancreatic contusions and lacerations without pancreatic duct injury have been designated as grade I or grade II by the American Association for the Surgery of Trauma (Table 2) and can frequently be managed conservatively. More severe injuries (grades III–V) involve the pancreatic duct or ampulla and generally require intervention, whether surgical or endoscopic. Figure 13 depicts a pancreatic laceration with associated ductal disruption that was confirmed at endoscopic retrograde pancreatography. The severity of pancreatic laceration has been shown to be predictive of ductal disruption (31). In a retrospective review of 22 cases of pancreatic injury, none of the 10 patients with superficial lacerations (<50% thickness) had a ductal injury, whereas eight of 10 patients with deep lacerations (>50% thickness) had disruption of the main pancreatic duct (31).

Endoscopic retrograde pancreatography or magnetic resonance (MR) pancreatography should be considered for assessment of the integrity of the pancreatic duct in the setting of suspected pancreatic injury. Focal findings may not be evident at initial CT and may take up to 24 hours to become radiologically apparent (26,28).

### Adrenal Injuries

Adrenal injuries are seen in up to 2% of patients with blunt abdominal trauma (32). Although isolated adrenal injuries are uncommon and can be relatively benign and self-limited, they are frequently associated with more significant abdominal and thoracic injuries. Liver injuries are the most common associated injury. When an adrenal injury is found, the radiologist should imagine the vector of force needed to cause such an injury and look along this line in the liver or kidney for other injuries. In a review of 73 cases of traumatic adrenal hemorrhage detected at CT, 77% of hemorrhages were right sided, 15% were left sided, and 8% were bilateral (32). Proposed mechanisms of adrenal injury include direct crush injury (ie, between the spine and the liver or spleen), injury due to acutely increased adrenal venous pressure transmitted from a compressed IVC, IVC–adrenal vein thrombosis, and shear injury to small adrenal vessels due to rotational or deceleration forces (32,33). Adrenal injuries are thought to occur more frequently on the right side due to the location of the right

<table>
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<tr>
<td>I</td>
<td>Minor contusion or laceration without ductal injury</td>
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<tr>
<td>II</td>
<td>Major contusion or laceration without ductal injury or tissue loss</td>
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<tr>
<td>III</td>
<td>Distal transection or pancreatic parenchymal injury with ductal injury</td>
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<tr>
<td>IV</td>
<td>Proximal transection or pancreatic parenchymal injury involving the ampulla</td>
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<td>V</td>
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Source.—Reference 20.
pararenal space, and thickening of the ipsilateral diaphragmatic crus can be seen (32,34). Adrenal hemorrhage is usually hyperattenuating (40–60 HU); does not enhance; is accompanied by periadrenal stranding; and will change over time, typically decreasing in size and, perhaps, eventually calcifying (32). An attenuation of less than 10 HU at unenhanced CT or washout of over 50% of contrast material after a 10-minute delay is consistent with an adrenal adenoma (35,36). If the cause of trauma is in doubt, adrenal protocol CT or MR imaging can be used to confirm the diagnosis or a follow-up examination can be performed in 6–8 weeks. An adrenal hemorrhage should resolve or shrink considerably in that time and will not enhance after contrast material administration, whereas an adrenal adenoma or malignant lesion will persist over time and will enhance (32,34). Figure 14 shows a typical right adrenal hemorrhage with periadrenal hemorrhage and stranding.
Figure 15 shows an infrarenal aortic injury with a concentric intimal flap due to lap belt use. More severe injuries include vessel laceration and transection, which necessitate emergent intervention.

Blunt injuries to the IVC are also rare, with only a few published reports in the literature (41,42). In a retrospective review of 5059 patients with blunt trauma over a 10-year period at a single center, 10 patients with blunt IVC injuries were identified (41). CT findings of blunt IVC injury vary depending on the location of the injury. Retroperitoneal hematoma with a paracaval epicenter, irregular IVC contour, and extravasation of contrast material have been described with infrahepatic IVC injury (41). With retrohepatic IVC injuries, severe associated liver trauma is often seen. Signs that are suggestive of retrohepatic IVC injury include extensive liver laceration into the porta hepatis and retrohepatic IVC region or an irregular contour of the retrohepatic IVC (41). Blunt IVC injuries can be difficult to diagnose, since many of the reported cases lack contrast material extravasation as direct evidence of vascular injury (41).

### Abnormal Findings within the Retroperitoneum Following Trauma

#### Retroperitoneal Hemorrhage
Retroperitoneal hemorrhage can be the source of significant but clinically occult blood loss in the trauma patient. Retroperitoneal hemorrhage was identified in 12% of 466 stable patients undergoing abdominal CT for blunt trauma at a major...
and stability, and the hemodynamic status of the patient. Options include surgical intervention, angiographic embolization, and observation with fluid support. The goals of imaging are to identify the retroperitoneal hemorrhage, its location, and its possible source and to assess its relative stability on the basis of the size and presence (or absence) of active extravasation of intravascular contrast material (45).

From a surgical standpoint, the retroperitoneum can be divided into zones because hematoma location has therapeutic implications (Fig 16; Table 3) (46). This classification scheme was initially described in the surgical literature in 1982 (46,47).
severity of the hemorrhage and may include exploration or angiographic embolization for large or expanding hematomas (48). Many perirenal and pericolonic hematomas are self-limiting, and patients can be treated with observation alone if they remain hemodynamically stable and no extraluminal gas or active extravasation of contrast material is identified at initial imaging (46,48). Follow-up imaging can be used to assess the stability of retroperitoneal hemorrhage when observation is chosen (45). Figure 19 shows a zone II hemorrhage from a renal laceration.

Zone III encompasses the pelvic retroperitoneum and is the most common location of retroperitoneal hemorrhage, frequently in association with pelvic fractures (43,44,48). Surgical inter-
data were shown to be 95% sensitive for the detection of thoracic spine fractures and 97% sensitive for the detection of lumbar spine fractures, compared with sensitivities of 62% and 86%, respectively, for conventional radiographs of the thoracic and lumbar spine (50). Similar sensitivities for the detection and classification of thoracic and lumbar spinal fractures were achieved with MPR images of the thoracic and lumbar spine from thoracoabdominal multidetector CT data, provided both thin (≤3-mm) sections and MPR images were used (51).

The presence of a paraspinal hematoma is an important sign of spinal injury and should prompt careful evaluation of the adjacent spinal elements and paraspinal musculature (52). Figures 20–22 show paraspinal hematomas due to spinal injuries following blunt abdominal trauma.

**Figure 19.** Large zone II (lateral) retroperitoneal hematoma in a 17-year-old boy who was involved in a high-speed motor vehicle collision. Contrast-enhanced CT scan shows right-sided perirenal and posterior pararenal retroperitoneal hematoma (white arrowheads) from a right renal laceration, with active extravasation of intravascular contrast material (black arrow) from a renal parenchymal injury. A laceration of the right kidney is also visible (black arrowhead). Note the hyperenhancing, thickened small bowel (white arrows) due to shock.

**Figure 20.** Paraspinal hematoma due to a burst fracture in a 19-year-old woman who was involved in a motor vehicle collision. (a) Contrast-enhanced CT scan obtained through the upper pelvis shows a paraspinal hematoma (arrowheads) that surrounds the L5 vertebral body. (b) CT scan (bone window) shows a burst fracture of L5 (arrow). (c) Sagittal reformatted CT image of the lumbar spine obtained from the initial acquisition data set better depicts the burst fracture, with posterior cortex retropulsion (arrow) and narrowing of the central spinal canal (arrowheads).
the thorax is more commonly seen, particularly in patients with a pneumothorax who are on mechanical ventilation (53). Airway injury anywhere from the pharynx to the alveolus can produce pneumomediastinum and, in turn, pneumoretroperitoneum. Esophageal perforation producing pneumomediastinum is another potential source of retroperitoneal air. The finding of pneumoretroperitoneum in the setting of trauma should be accounted for on the basis of retroperitoneal injury or air tracking into the retroperitoneum from the chest. Figure 23 shows pneumoretroperitoneum from mediastinal air tracking into the retroperitoneum following an airway injury.

Retroperitoneal Air

The presence of retroperitoneal air should raise suspicion for a perforated retroperitoneal viscus in the setting of both blunt and penetrating abdominal trauma. Isolated pneumoretroperitoneum in the anterior pararenal space adjacent to the duodenum is suggestive of a duodenal perforation (53). Likewise, localized pericolonic retroperitoneal air is suggestive of colonic perforation (54). Pneumoretroperitoneum from communications between the retroperitoneum and the thorax is more commonly seen, particularly in patients with a pneumothorax who are on mechanical ventilation (53). Airway injury anywhere from the pharynx to the alveolus can produce pneumomediastinum and, in turn, pneumoretroperitoneum. Esophageal perforation producing pneumomediastinum is another potential source of retroperitoneal air. The finding of pneumoretroperitoneum in the setting of trauma should be accounted for on the basis of retroperitoneal injury or air tracking into the retroperitoneum from the chest. Figure 23 shows pneumoretroperitoneum from mediastinal air tracking into the retroperitoneum following an airway injury.
vere trauma that can result as a response to shock (55). Imaging findings of hypoperfusion shock complex include diffusely thickened, enhancing bowel; hyperenhancing parenchymal organs; and decreased caliber of the aorta and IVC. Extracellular fluid is frequently present and can be seen surrounding the pancreas, within other retroperitoneal spaces, and within the pelvis in the absence of retroperitoneal injury (Fig 24) (55,58).

**Figure 23.** Retroperitoneal air in a 40-year-old man who was involved in a motor vehicle collision. The patient, who had bilateral pneumothoraces, underwent bilateral chest tube placement and was placed on mechanical ventilation. (a) Abdominal CT scan obtained with intravenous contrast material shows extraluminal air (arrowheads) in the right perirenal space, in the anterior pararenal space, and along the fascial planes of the abdominal musculature. (b) Coronal MPR CT image of the chest and abdomen (lung window) shows extensive pulmonary contusions, subcutaneous emphysema, and mediastinal and retroperitoneal air. A right upper lobe bronchial laceration with a resultant air leak was discovered.

**Figure 24.** Retroperitoneal fluid without retroperitoneal organ injury. (a) Abdominal CT scan shows fluid within the anterior pararenal space (arrowheads) diffusely surrounding the pancreas. (b) CT scan shows thickening and hyperenhancement of the small bowel (arrows), findings that are due to hypoperfusion shock complex with extracellular fluid accumulation following shock and resuscitation. Pancreatic enzyme levels were not elevated. No intraabdominal injury could be identified.

**Retroperitoneal Fluid**

The presence of fluid within the retroperitoneum in the setting of trauma should raise suspicion for pancreatic injury, duodenal injury, renal collecting system injury (with urine leakage), or retroperitoneal hemorrhage. However, low-attenuation (<20 HU) retroperitoneal fluid accumulation can be seen in the absence of retroperitoneal injury (55–57). Hypoperfusion shock complex is an infrequently encountered entity in victims of severe trauma that can result as a response to shock (55). Imaging findings of hypoperfusion shock complex include diffusely thickened, enhancing bowel; hyperenhancing parenchymal organs; and decreased caliber of the aorta and IVC. Extracellular fluid is frequently present and can be seen surrounding the pancreas, within other retroperitoneal spaces, and within the pelvis in the absence of retroperitoneal injury (Fig 24) (55,58).
Retroperitoneal fluid accumulation can be seen in the setting of abdominal compartment syndrome, resulting from pathologic elevation of intraabdominal pressure. In a small retrospective review of four patients with surgically proved abdominal compartment syndrome, common CT findings included dense infiltration of the retroperitoneum out of proportion to the peritoneal disease, extrinsic compression of the IVC by retroperitoneal hemorrhage or exudates, and massive abdominal distention (56). Renal compression, inguinal herniation, and bowel wall thickening with enhancement can also be seen. Because abdominal compartment syndrome requires emergent surgical decompression, radiologic findings of increased intraabdominal pressure should be promptly communicated to other physicians involved in treating the patient (56,59).

Resuscitation effects alone can result in the appearance of low-attenuation retroperitoneal fluid (58). Concomitant intrahepatic periportal low attenuation (ie, edema) may be present, even in the absence of hepatic injury (58). The proposed mechanism is elevated central venous pressure caused by rapid expansion of intravascular volume (60). In addition, small amounts of fluid can be seen in the dependent portion of the peritoneal pelvic cavity due to the same mechanism (57). The radiologist must exclude underlying injury—particularly injury to the pancreas, duodenum, or renal collecting system—before concluding that the presence of low-attenuation retroperitoneal fluid is likely the result of resuscitation or shock. Because both pancreatic and duodenal injuries can be subtle at initial CT, close clinical observation with possible imaging follow-up should be considered in cases of equivocal CT findings (17,42).

**Diagnostic Approach**

Our proposed algorithm for the diagnosis of traumatic retroperitoneal injuries includes the following considerations:

1. Recognize abnormal blood, fluid, or air in the retroperitoneum that may be the clue to subtle organ injury.
2. If initial CT yields abnormal but equivocal retroperitoneal findings, close clinical observation with possible imaging follow-up should be considered, particularly in the presence of an appropriate injury mechanism, associated injuries, a rising serum amylase level, persistent abdominal pain, or clinical signs of retroperitoneal injury (4,17,42).
3. If fluid is found in the retroperitoneum, try to determine the source and note whether the fluid is diffuse or focal.
4. Look for a sentinel clot.
5. Seek out active extravasation near the largest clot or the sentinel clot.
6. Duodenal perforation and complete pancreatic transection necessitate urgent surgery (4).
7. Active extravasation can be managed angiographically or surgically.

**Conclusions**

Assessment of the retroperitoneum is critical in the radiologic evaluation of patients who have sustained blunt abdominal trauma. Multidetector CT can allow accurate posttraumatic assessment of patients, including the detection of retroperitoneal injuries, which can be subtle (2). Recognition of abnormal blood, fluid, or air within the retroperitoneal spaces is the key to correctly identifying duodenal, pancreatic, vascular, renal, adrenal, and paraspinal injuries (1,7,10). Equivocal findings at initial abdominal CT should prompt close clinical follow-up with possible imaging follow-up, particularly for suspected occult duodenal and pancreatic injuries (4,17,42).

**References**


Traumatic Retroperitoneal Injuries: Review of Multidetector CT Findings

Kevin P. Daly, MD, et al

Accurate radiologic characterization of injury can help in selecting patients who need urgent surgical intervention, as opposed to those in whom nonoperative management is possible, particularly since the morbidity rate for an unnecessary laparotomy (ie, completely negative findings or nontherapeutic results) in the setting of trauma is between 8.6% and 25.9%.

Extraluminal air is a reliable sign of duodenal perforation and is highly predictive of such perforation in the absence of pneumothorax or prior diagnostic peritoneal lavage.

Because of the high morbidity and mortality rates associated with delayed treatment, the trauma team and radiologist should remain vigilant if there is a high degree of suspicion for pancreatic injury based on injury mechanism, clinical findings, or unexplained hyperamylasemia.

The goals of imaging are to identify the retroperitoneal hemorrhage, its location, and its possible source and to assess its relative stability on the basis of the size and presence (or absence) of active extravasation of intravascular contrast material.

Recognition of abnormal blood, fluid, or air within the retroperitoneal spaces is the key to correctly identifying duodenal, pancreatic, vascular, renal, adrenal, and paraspinal injuries.
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Number of reprints ordered $_________
Number of color reprints ordered $_________
Number of covers ordered $_________
Subtotal $_________
Taxes $_________
(Add appropriate sales tax for Virginia, Maryland, Pennsylvania, and the
District of Columbia or Canadian GST to the reprints if your order is to
be shipped to these locations.)

First address included, add $32 for
each additional shipping address $_________

TOTAL $_________

Shipping Address (cannot ship to a P.O. Box) Please Print Clearly
Name ___________________________________________
Institution _________________________________________
Street ___________________________________________
City ____________________  State _____  Zip  ___________
Country ___________________________________________
Quantity ____________________  Fax ___________________
Phone:  Day _______________ Evening _______________
E-mail Address _____________________________________

Additional Shipping Address* (cannot ship to a P.O. Box)
Name ___________________________________________
Institution _________________________________________
Street ___________________________________________
City ____________________  State _____  Zip  ___________
Country ___________________________________________
Quantity ____________________  Fax ___________________
Phone:  Day _______________ Evening _______________
E-mail Address _____________________________________
* Add $32 for each additional shipping address

Payment and Credit Card Details

Enclosed: Personal Check ___________
Credit Card Payment Details ___________
Checks must be paid in U.S. dollars and drawn on a U.S. Bank.
Credit Card: __ VISA    __ Am. Exp.    __ MasterCard
Card Number __________________________________
Expiration Date ____________________________
Signature: __________________________________

Please send your order form and prepayment made payable to:
Cadmus Reprints
P.O. Box 751903
Charlotte, NC  28275-1903

Note: Do not send express packages to this location, PO Box.
FEIN #:541274108

Invoice or Credit Card Information

Invoice Address Please Print Clearly
Please complete invoice address as it appears on credit card statement
Name ___________________________________________
Institution _________________________________________
Department ____________________________
Street ___________________________________________
City ____________________  State _____  Zip  ___________
Country ___________________________________________
Phone ____________________________  Fax ___________________
E-mail Address _____________________________________

Cadmus will process credit cards and Cadmus Journal
Services will appear on the credit card statement.

If you don’t mail your order form, you may fax it to 410-820-9765 with
your credit card information.

Signature __________________________________ Date ______________________
Signature is required. By signing this form, the author agrees to accept the responsibility for the payment of reprints and/or all charges
described in this document.
### Black and White Reprint Prices

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### Domestic (USA only)

**International (includes Canada and Mexico)**

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### Tax Due

Residents of Virginia, Maryland, Pennsylvania, and the District of Columbia are required to add the appropriate sales tax to each reprint order. For orders shipped to Canada, please add 7% Canadian GST unless exemption is claimed.

### Ordering

Reprint order forms and purchase order or prepayment is required to process your order. Please reference journal name and reprint number or manuscript number on any correspondence. You may use the reverse side of this form as a proforma invoice. Please return your order form and prepayment to:

**Cadmus Reprints**
P.O. Box 751903  
Charlotte, NC  28275-1903

**FEIN #:541274108**

Please direct all inquiries to:

**Rose A. Baynard**
800-407-9190 (toll free number)  
410-819-3966 (direct number)  
410-820-9765 (FAX number)  
baynadr@cadmus.com (e-mail)