Multidetector CT of Blunt Traumatic Venous Injuries in the Chest, Abdomen, and Pelvis

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Venous injuries as a result of blunt trauma are rare. Even though current protocols for multidetector computed tomography (CT) of patients with trauma are designed to evaluate primarily the solid organs and arteries, blunt venous injuries may nevertheless be identified, or at least suspected, on the basis of the multidetector CT findings. Venous injuries are associated with high morbidity and mortality rates. Diagnosis of a possible venous injury is crucial because the physical findings of a venous injury are nonspecific and may be absent. This article aims to make the radiologist aware of various venous injuries caused by blunt trauma and to provide helpful hints to aid in the identification of venous injuries. Multidetector CT technology, in combination with interactive manipulation of the raw dataset, can be useful in the creation of multiplanar reconstructed images and in the identification of a venous injury caused by blunt trauma. Familiarity with direct and indirect signs of venous injuries, as well as with examples of blunt traumatic venous injuries in the chest, abdomen, and pelvis, will help in the diagnosis of these injuries.

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Abbreviation: IVC = inferior vena cava

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Introduction

Venous injuries caused by blunt trauma are an uncommon imaging finding, likely because of the comorbid trauma-related injuries that either result in death or cause hemodynamic instability requiring immediate surgical intervention before imaging (1). Thus, identification of these blunt trauma–related venous injuries on multidetector computed tomographic (CT) images obtained at admission is important because the clinical signs and symptoms of venous injuries are either nonspecific or absent and because primary attention may be given to the more common and obvious injuries. Today’s modern multidetector CT scanners are able to provide superior image detail, and multidetector CT has become the primary imaging modality for the initial evaluation of the patient with blunt trauma. Current protocols for evaluating trauma with multidetector CT are designed to look for the most common trauma-related injuries, primarily arterial and solid organ injuries. In addition, venous opacification, even during the portal venous phase, is often less than that of the arterial structures during the arterial phase because of hemodilution of the contrast material and its elimination by the kidneys. This lessened venous opacification may create inherent and unavoidable limits in the evaluation of the venous structures. Therefore, it is imperative for the radiologist to understand that although current imaging protocols are not designed specifically to evaluate the venous system, venous injuries may nevertheless be identified, with the potential for important alteration of management.

The purpose of this article is to make the radiologist aware of various venous injuries caused by blunt trauma and to provide helpful hints to aid in the identification of venous injuries. First, the multidetector CT protocol is presented. Then blunt traumatic venous injuries are covered for the following specific veins: brachiocephalic vein, azygos vein, superior vena cava, pulmonary vein, inferior vena cava (IVC), main portal vein, hepatic veins, mesenteric veins, splenic vein, renal vein, and iliac vein.

Multidetector CT Protocol

The goal of the protocol is to maximize the identification of the most common and potentially important injuries, primarily solid organ and arterial injuries. Thus, at our institution, all patients who have sustained blunt trauma routinely undergo intravenous contrast material–enhanced multidetector CT of the neck, chest, abdomen, and pelvis (whole-body multidetector CT) in the arterial phase, as well as 90-second delayed imaging through the abdomen and pelvis (portal venous phase), as directed by the attending trauma surgeon. Delayed phase imaging is not routinely included; however, if there is concern about an injury to the renal collecting system or if the findings from the initial whole-body multidetector CT examination reveal a renal injury that is associated with an increased likelihood of a collecting system injury, then an additional 3-minute delayed phase imaging examination is performed. Standard portal venous phase imaging is designed to identify solid organ injuries but, as the name implies, also results in opacification of the venous structures. Therefore, the radiologist has to use all available tools to evaluate the venous structures if there is a concern about injury. These tools can often include multiplanar reconstructed images, with close attention to subtle findings of venous injuries.

The CT scanning parameters for a typical whole-body multidetector CT examination with the two dedicated trauma CT scanners at our institution are detailed in the Table. At our institution, 2-mm axial and coronal images are routinely generated by the technologist for review at a picture archiving and communication system (PACS) workstation. The raw data are also available to the radiologist for further evaluation and creation of multiplanar reformatted images in any plane by using a commercially available volume viewer. Multiplanar reformatted images tailored to the specific anatomic structures in question allow visualization of the structures in nonaxial planes, which may display the injury in a more intuitive fashion. Often, a definite venous injury cannot be identified on the images from the admission CT examination, but the findings on these images can be suggestive of a venous injury. In these instances, further imaging or interventional recommendations can be made on the basis of the whole-body multidetector CT findings.

In many cases of traumatic venous injury, there is a potential role for treatment by an interventional radiologist. Advances in the techniques for insertion of an endovascular stent and the techniques for embolization now provide an alternative to open surgical exploration. A detailed discussion is beyond the scope of this article, but the radiologist and trauma surgeon are encouraged to seek consultation with an interventional radiologist in these cases.

Venous Injuries

Venous injuries are much more common in the setting of penetrating trauma (1), particularly after attempts at central venous catheter placement.
Venous injuries can be identified at CT by finding either direct or indirect signs of the injury. Direct signs of vascular injury are diagnostic and include thrombosis and/or occlusion, avulsion and/or complete tear, rupture, active extravasation, and pseudoaneurysm. Indirect signs of venous injury, such as perivascular hematoma, fat stranding, and vessel wall irregularity, are indeterminate findings because a venous injury may or may not be present. These indirect signs can often be seen in association with other adjacent injuries. **Brachiocephalic Vein**

Blunt injury to the brachiocephalic vein is rare and is seen most commonly in the setting of iatrogenic penetrating trauma, such as central venous catheter insertion (2). Dislocation of the sternoclavicular joint accounts for only 2%–3% of all shoulder dislocations and can be difficult to diagnose clinically. Posterior dislocation of the clavicular head can often be associated with vascular injuries in the anterior mediastinum (3). Therefore, any case of posterior dislocation of the clavicle (Fig 1) should raise concern about an associated vascular injury.

**Table:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>40-Section Scanner</th>
<th>64-Section Scanner</th>
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<td>64 × 0.625 mm</td>
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<tr>
<td>Contrast material</td>
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<tr>
<td>Volume injected (mL)</td>
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<td>100</td>
</tr>
<tr>
<td>Injection rate (mL/sec)</td>
<td>4–6</td>
<td>4–6</td>
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*Detector configuration: number of sections (detectors) × section thickness.

**Figure 1.** Posterior sternoclavicular dislocation in a 43-year-old woman after blunt trauma. (a, b) Axial (a) and coronal (b) contrast-enhanced CT images show narrowing (arrow) of the distal left brachiocephalic vein. Evaluation of the right subclavian and brachiocephalic veins was limited because of contrast material injection from the left side. Therefore, venography was performed. (c) Anteroposterior venographic image depicts occlusion (solid arrow) of the right subclavian vein secondary to the posteriorly dislocated clavicle. The occlusion causes dilation of the collateral veins (open arrows).
All mediastinal hematomas are abnormal and raise concern about a vascular injury, particularly an injury of the aorta or aortic arch vessel (4,5). In addition to mediastinal hematomas that result from arterial injuries, mediastinal hematomas can also be the result of venous injuries, small vessel injuries, and fractures of the sternum. Azygos vein injuries can be a rare cause of mediastinal hematoma after blunt trauma. Adjacent spinal fractures can cause injury to the azygos vein, but this is not always the case. Evaluation of the mediastinum in multiple planes is often helpful for localizing a focus of active bleeding or a pseudoaneurysm (Fig 2), as well as other associated vascular injuries.

**Superior Vena Cava**

Injuries to the superior vena cava are extremely rare because patients with these injuries almost universally die because of them and other associated injuries. Superior vena cava injuries are seen most commonly in the setting of penetrating trauma. When they do occur, blunt injuries to the superior vena cava are commonly seen near its insertion into the right atrium (Fig 3) (6), where it is enveloped by the pericardium (7). Coexisting injury to the right atrium is common.

**Pulmonary Vein**

Few cases of pulmonary vein injuries caused by blunt trauma have been reported in the literature because such injuries are strongly associated with other severe comorbid injuries, including injuries to the atria, ventricles, main-stem bronchi, pericardium, and aorta (8). These patients commonly present with hypotension, hypovolemia, and massive hemothorax (9). As with superior vena cava injuries, pulmonary vein injuries can be intrapericardial or extrapericardial; the former type is associated with hemopericardium with or without
cardiac tamponade, depending on the presence of a pericardial tear, and the latter type is associated with hemothorax (8). CT findings of pulmonary vein injuries depend on the location of the tear with respect to the pericardium.

**Inferior Vena Cava**

Injuries to the IVC are associated with high morbidity and mortality rates. Investigators have reported that more than one-third of patients with an IVC injury die before reaching the hospital, and in-hospital mortality is greater than 60% (10,11). Given the high mortality and the common occurrence of other severe comorbid injuries, IVC injuries are not commonly diagnosed at imaging. Any subtle abnormality depicted on axial or standard multiplanar images (Fig 4) should prompt (a) further evaluation with oblique nonstandard multiplanar reformatted images on an interactive volume-viewing station or (b) additional imaging. Imaging options include conventional venography and CT venography. Few to no data exist to compare conventional venography to CT venography for the evaluation of the IVC in the setting of trauma. Therefore, if further imaging is deemed necessary, each case should be considered individually on the basis of the patient’s clinical presentation and factors such as renal function and the likelihood of intervention being required.

Injuries to the IVC are often associated with severe hepatic injuries and other adjacent injuries, and thus the radiologist should be even more concerned about possible IVC injury in the setting of nearby injuries (Fig 5). The radiologist

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**Figure 4.** IVC injuries in a 38-year-old woman after blunt trauma. (a) Axial contrast-enhanced CT image shows a subtle contour irregularity (arrow) of the IVC. (b) Multiplanar reformatted image that is focused on the region of the contour abnormality depicted in a shows a small intimal flap (arrow). (c) Follow-up cavogram helps confirm an abnormality (arrow) of the IVC, a finding consistent with a small intimal tear and formation of a small pseudoaneurysm.

**Figure 5.** IVC injuries in a 27-year-old man after blunt trauma. (a) Axial CT image of the infrarenal portion of the IVC depicts a hematoma (arrow) around the IVC. (b) A more inferior axial CT image from the same study shows a laceration through the IVC just proximal to the bifurcation, with associated intimal flaps and intraluminal thrombi (arrow).
Figure 6. Large hemopericardium and IVC injury in a 63-year-old woman after severe blunt chest and abdominal trauma. (a) Axial contrast-enhanced CT image obtained in the arterial phase shows a small focus of hyperattenuation (arrow) in the right inferior pericardial space. (b) Axial contrast-enhanced CT image obtained in the portal venous phase shows enlargement of the focus of hyperattenuation (arrow). Intrapericardial rupture of the IVC was confirmed at surgery, and the patient died during surgery.

Figure 7. Main portal vein dissection in a 30-year-old man after blunt abdominal trauma. Axial (a) and coronal (b) contrast-enhanced CT images show a periportal and perihepatic hematoma (arrowheads in a). An intimal flap (arrow) is depicted in the main portal vein. The patient was treated conservatively, and the intimal flap was not seen at follow-up imaging.

should also be aware that retrohepatic IVC injuries are a special case and often require a complicated surgical approach including both a laparotomy and thoracotomy. Accurately identifying the location of the IVC injury can aid in surgical planning. A common imaging pitfall is mixing of unenhanced blood with contrast material, which can simulate a thrombosis or vessel injury. Hemopericardium is a rare manifestation of an IVC injury, but IVC injury should remain
Figure 8. Main portal vein injuries in a 63-year-old woman after blunt abdominal trauma. Axial contrast-enhanced CT images obtained at different levels (a, b) demonstrate a contour abnormality and an intimal flap (black arrow) in the portal vein. Trace surrounding fat stranding (white arrows) indicates a hematoma.

in the differential diagnosis of hemopericardium (Fig 6).

Main Portal Vein
Injuries to the main portal vein are rare and can be difficult to diagnose. When they occur, main portal vein injuries are often seen with associated injuries to the liver, pancreatic duct, and bile duct (12). Indirect signs of a vascular injury, such as perivascular hematoma (Fig 7) or fat stranding of the surrounding mesentery (Fig 8), may be subtle or nearly imperceptible, even in the presence of a substantial underlying vascular injury. Identification of these injuries is important because they can require aggressive surgical treatment, although the cases presented herein were managed conservatively. Injury to the intrahepatic portal veins is also possible and, in the setting of a traumatic arteriovenous fistula, can manifest with early filling of the portal veins with contrast material at the trauma CT examination. This finding should prompt further evaluation with arteriography to determine diagnostic and therapeutic options.

Hepatic Veins
Small hepatic venous injuries are relatively common in the setting of liver parenchymal injuries, and bleeding typically stops spontaneously. Bleeding from hepatic venous injuries closer to the liver hilum or from one of the major hepatic veins is less likely to be controlled without intervention (13). In addition, early filling of hepatic veins with contrast material on the images from the trauma CT examination should raise concern for an associated arteriovenous fistula, which can be evaluated further with arteriography. Additional signs of hepatic venous injury include hepatic laceration extending into or through a hepatic or portal vein, vessel irregularity, or abrupt cutoff.

Mesenteric Veins
Mesenteric vascular injuries are unusual but are associated with considerable morbidity and mortality, with rates as high as 60%. Mesenteric vascular injuries are frequently associated with bowel injuries, and therefore prompt diagnosis and treatment are essential (14–16). Clinical signs and symptoms of mesenteric or bowel injury are nonspecific, and thus imaging plays a vital role in the diagnosis (15,16). An area of active extravasation can be correlated with regional vascular structures and the phase of contrast-enhanced imaging to provide a clue as to the source of the bleeding (Fig 9), but it may be difficult or impossible to differentiate whether the source is arterial or venous.
**Splenic Vein**

Traumatic injury to the main splenic vein is exceedingly rare, and when such injury is seen, it is usually a result of penetrating trauma (17,18). Injury to the small intrasplenic veins occurs in the setting of a blunt traumatic injury to the spleen. As in intrahepatic injuries, early filling of the splenic vein with contrast material should prompt further evaluation with arteriography.

**Renal Vein**

The renal pedicle is not immune to injury in the setting of blunt trauma. Injuries to the pedicle are more likely to occur in association with renal parenchymal injuries. Isolated renal vein injuries are a rare form of renal vascular pedicle injury, but they do exist (19–21). Careful evaluation of the delayed phase images for expanding hematoma is essential because this finding indicates a vascular injury with continued active bleeding. Multiplanar and three-dimensional images may display the vascular injury in a more intuitive way (Fig 10).

**Iliac Vein**

Pelvic fractures are typically associated with considerable blunt force trauma, and associated vascular injuries are identified frequently (22). Arterial injuries are more common, but venous injuries are possible and should not be discounted in the setting of pelvic fractures and hematoma (22) (Fig 11). In the recent literature,
Figure 10. Renal vein injury in a 35-year-old woman after blunt trauma from a motor vehicle collision. (a) Axial contrast-enhanced CT image obtained in the late arterial phase shows decreased perfusion of the left kidney (arrow) and a large perirenal hematoma (arrowheads). (b) Coronal contrast-enhanced CT image obtained in the late arterial phase shows the abnormal contour (arrow) of the distal end of the left renal vein; the extravasation of contrast material has attenuation that mirrors that of the venous system. (c) Axial contrast-enhanced CT image obtained in the delayed phase depicts accumulation of high-attenuation material (arrows) within the perirenal tissues, a finding that is consistent with active venous extravasation into the surrounding tissues. Renal vein injury was confirmed at surgery.

Figure 11. Pelvic fractures and hematoma in a 41-year-old man after blunt trauma. (a) Axial contrast-enhanced CT image shows active extravasation (arrowheads) into a large hematoma in the left hemipelvis. The external iliac artery (arrow) is intact, but the vein is not depicted clearly. (b) Axial contrast-enhanced CT image obtained at a different level during the same study again shows an intact external iliac artery (white arrow). The external iliac vein (black arrow), however, is irregular and is surrounded by extravasated contrast material (arrowhead) and hematoma. The patient also had a bowel injury associated with mesenteric bleeding secondary to a mesenteric avulsion (not shown).
Anderson et al (23) have suggested that if pelvic CT angiography is performed (arterial, portal venous, and delayed phases), the radiologist can distinguish reliably between arterial and venous extravasation.

**Conclusions**

Although current recommended multidetector CT protocols for trauma are not designed to routinely evaluate venous structures, venous injuries do occur and may be identified on, or at least suggested by, routine multidetector CT images. Signs and symptoms of venous injuries are non-specific, and such injuries may not be suspected clinically; thus the radiologist is positioned to make major contributions to the care of these patients. Further imaging recommendations can then be made on the basis of these findings. The radiologist should be aware of both direct and indirect signs of venous injury and should understand that the use of multiplanar reformatted images and three-dimensional volume-rendered images may be useful in the diagnosis and evaluation of venous trauma.

**References**

Therefore, it is imperative for the radiologist to understand that although current imaging protocols are not designed specifically to evaluate the venous system, venous injuries may nevertheless be identified, with the potential for important alteration of management.

Multiplanar reformatted images tailored to the specific anatomic structures in question allow visualization of the structures in nonaxial planes, which may display the injury in a more intuitive fashion.

Direct signs of vascular injury are diagnostic and include thrombosis and/or occlusion, avulsion and/or complete tear, rupture, active extravasation, and pseudoaneurysm.

Indirect signs of venous injury, such as perivascular hematoma, fat stranding, and vessel wall irregularity, are indeterminate findings because a venous injury may or may not be present. These indirect signs can often be seen in association with other adjacent injuries.

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