Imaging of Renal Trauma: A Comprehensive Review[1]

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CME FEATURE

See accompanying test at http://www.rsna.org/education/rg_cme.html

LEARNING OBJECTIVES FOR TEST 1

After reading this article and taking the test, the reader will be able to:

- Describe the spectrum of posttraumatic renal injuries.
- Identify the key imaging features of trauma-related renal injury.
- Correlate the clinical and imaging findings in renal trauma.

Computed tomography (CT) is the modality of choice in the evaluation of blunt renal injury. Intravenous urography is used primarily for gross assessment of renal function in hemodynamically unstable patients. Selective renal arteriography or venography can provide detailed information regarding vascular injury. Retrograde pyelography is valuable in assessing ureteral and renal pelvic integrity in suspected ureteropelvic junction injury. Ultrasonography is useful in detecting hemoperitoneum in patients with suspected intraperitoneal injury but has limited value in evaluating those with suspected extraperitoneal injury. Occasionally, radionuclide renal scintigraphy or magnetic resonance imaging may prove helpful. Renal injuries can be classified into four large categories based on imaging findings. Category I renal injuries include minor cortical contusion, subcapsular hematoma, minor laceration with limited perinephric hematoma, and small cortical infarct. Category II lesions include major renal lacerations extending to the medulla with or without involvement of the collecting system and segmental renal infarct. Category III lesions are catastrophic renal injuries and include multiple renal lacerations and vascular injury involving the renal pedicle. Category IV injuries are ureteropelvic junction injuries. CT is particularly useful in evaluating traumatic injuries to kidneys with preexisting abnormalities and can help assess the extent of penetrating injuries in selected patients with limited posterior stab wounds. Integration of the imaging findings in renal injury with clinical information is critical in developing a treatment plan.

Index terms: Kidney, CT, 81.1211 • Kidney, infarction, 81.77 • Kidney, injuries, 81.41, 81.77 • Renal angiography, 81.124 • Renal arteries, injuries, 961.41 • Trauma, 81.40

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Introduction

Injury to the kidney is seen in approximately 8%–10% of patients with blunt or penetrating abdominal injuries (1). The vast majority (80%–90%) of cases involve blunt rather than penetrating injury (1). Serious renal injuries are frequently associated with injuries to other organs; multiorgan involvement occurs in 80% of patients with penetrating trauma and in 75% of those with blunt trauma (2,3). The vast majority (98%) of isolated renal injuries are classified as minor injuries (4).

In this article, we describe the indications for radiologic assessment of renal injury and the role that various imaging modalities (computed tomography [CT], intravenous urography, angiography, retrograde pyelography, ultrasonography [US], radionuclide renal scintigraphy, magnetic resonance [MR] imaging) play in patient treatment. In addition, we describe a radiologic classification system for renal injuries following blunt trauma with an emphasis on CT findings. We also discuss and illustrate penetrating renal injury, traumatic injuries to kidneys with preexisting abnormalities, and urologic complications in renal injury.

Indications for Imaging Evaluation

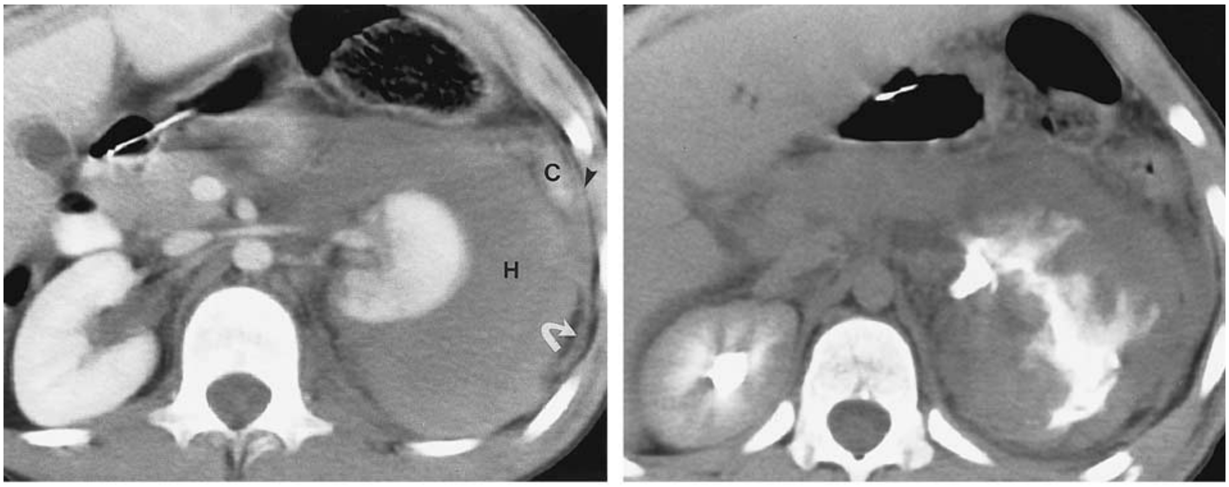
In general, hematuria (>5 red blood cells per high-power field) is present in over 95% of patients who sustain renal trauma (1). However, the absence of hematuria does not preclude significant renal injury; its absence has been reported in up to 24% of patients with thrombosis of the renal artery (5) and in one-third of cases of ureteropelvic junction injury (6). In a study conducted to refine the indications for radiologic assessment, Nicolaisen et al (7) found major renal injuries at intravenous urography in 23 of 85 consecutive patients with hematuria and shock; there were no major renal injuries in 221 consecutive patients with microscopic hematuria and no shock. Similar results have been reported at other institutions (4,8,9). At our institutions, radiographic evaluation of the urinary tract is performed in patients with penetrating injury and hematuria, blunt trauma if associated with gross hematuria, microscopic hematuria and hypotension (blood pressure <90 mm Hg at any time during the evaluation), or microscopic hematuria and significant associated injuries (9,10). Radiologic investigation of the kidney is also warranted after blunt trauma in patients with other injuries known to be associated with renal injury (eg, direct contusion or hematoma of flank soft tissues; fractures of the lower ribs, transverse processes, or thoracolumbar spine) (9). Children with blunt trauma and hematuria should undergo renal imaging regardless of blood pressure or degree of hematuria (1,11).

Imaging Modalities

Computed Tomography

CT has replaced intravenous urography as the primary modality for the assessment of suspected renal injuries. CT is more sensitive and specific than urography in the detection and characterization of suspected renal injury (8,12–14) and has become the imaging method of choice for the assessment of blunt abdominal injuries in major trauma centers in the Unites States (10). CT can provide precise delineation of a renal laceration, help determine the presence and location of a renal hematoma with or without active arterial extravasation, and indicate the presence of urinary extravasation or of devascularized segments of renal parenchyma. Most important, CT can help differentiate trivial injuries from those requiring intervention.

Early and delayed CT scans through the kidneys are necessary. The preferred technique consists of helical CT performed from the dome of the diaphragm 70 seconds after the initiation of intravenous administration of 150 mL of 60% nonionic iodinated contrast material with a mechanical power injector at an injection rate of 2.0–2.5 mL/sec. Scanning parameters include a collimation of 7 mm, a pitch of 1.3, and image reconstruction intervals of 7 mm. This scan delay allows optimal vascular enhancement, which helps identify severe injuries to the liver and spleen such as active bleeding (15–17). This protocol typically results in the kidneys being scanned approximately 80 seconds after the initiation of contrast material injection, during the late cortical or early homogeneous nephrographic phase. Optimal contrast material enhancement can also be achieved with use of an optional software upgrade (SmartPrep; GE Medical Systems, Milwaukee, Wis), which allows visual monitoring of the time–contrast material enhancement tracking curve by means of a series of low-milliamperage scans and region-of-interest attenuation measurements (18). Excretory-phase contrast material–enhanced CT through the kidneys performed 3 or more minutes after initiation of contrast material administration is necessary for complete assessment of a suspected renal injury so that a collecting system injury will not be overlooked (Fig 1) (19).



a. b.

Figure 1. Urine extravasation from the collecting system in a 9-year-old boy who had sustained blunt abdominal trauma. **(a)** Contrast-enhanced generalized-nephrographic-phase helical CT scan reveals what appears to be only a large perinephric hematoma (*H*) secondary to a distinct renal laceration (not shown). Because this is an early-phase image, there is no contrast material in the collecting system. The descending colon (*C*) is displaced anteriorly by the hematoma. Note the thickening of the renal (arrow) and lateroconal (arrowhead) fascia. **(b)** Excretory-phase CT scan demonstrates extensive extravasation of contrast-enhanced urine admixed with the hematoma, a finding that demonstrates that the laceration has disrupted the integrity of the collecting system.

Helical CT continues to evolve with the introduction of the new-generation scanners. With the development of a subsecond scanner and the more recent production of the multidetector array scanner, a larger area can be covered with similar collimation. Motion artifacts can be minimized with the shorter acquisition time. When multidetector array techniques are used, collimation can be retrospectively changed. Faster scanning techniques can optimize the timing of renal imaging during a given phase of contrast material excretion. We used a multidetector helical scanner (QX/i LightSpeed, GE Medical Systems) with the following parameters: 4 × 5.0-mm detector configurations, 3.0 pitch, 15.0-cm/sec table speed, and 7.5-mm section thickness. Image reconstruction at 5-mm intervals can be performed retrospectively when vascular injury is suspected. Multiplanar reformatted and three-dimensional images generated from axial source images can provide a great deal of additional information.

Intravenous Urography

Although urography is no longer the primary modality for the assessment of suspected renal injuries, in situations in which there would be a significant delay in obtaining high-quality CT scans, high-dose intravenous urography with nephrotomography can be performed for renal assessment (7,11). When urographic findings are abnormal, however, CT is necessary to help determine the nature and extent of a parenchymal injury.

The primary role for intravenous urography is the assessment of gross function and the evaluation of the uninjured kidney in hemodynamically unstable patients (7). Limited intravenous urography (“one-shot intravenous pyelography”) can be performed in patients who are brought to a trauma room in the emergency department and may be too unstable to undergo CT and in those who are already in the operating room. This procedure frequently consists of more than just one exposure and should include a scout radiograph as well as additional images obtained immediately after intravenous administration of iodinated contrast material and again 5–10 minutes later.

Angiography

The use of arteriography in the assessment of renal injuries has diminished because most vascular injuries can be assessed with CT. However, selective renal arteriography can provide more detailed information regarding the exact anatomic area of vascular injury than is possible with CT. Arteriography with transcatheter embolization may be used for nonsurgical therapy in hemodynamically stable patients with renal injuries associated with ongoing hemorrhage and for the evaluation of suspected vascular complications of injury (eg, arteriovenous fistula, pseudoaneurysm).

Venography may be performed to assess suspected injuries to the renal veins or inferior vena cava.

Radiologic Classification of Renal Injuries

Category	Description
I	Minor injury (renal contusion, intrarenal and subcapsular hematoma, minor laceration with limited perinephric hematoma without extension to the collecting system or medulla, small subsegmental cortical infarct)
II	Major injury (major renal laceration through the cortex extending to the medulla or collecting system with or without urine extravasation, segmental renal infarct)
III	Catastrophic injury (multiple renal lacerations, vascular injury involving the renal pedicle)
IV	Ureteropelvic junction injury (avulsion [complete transsection], laceration [incomplete tear])

Source.—Reference 27.

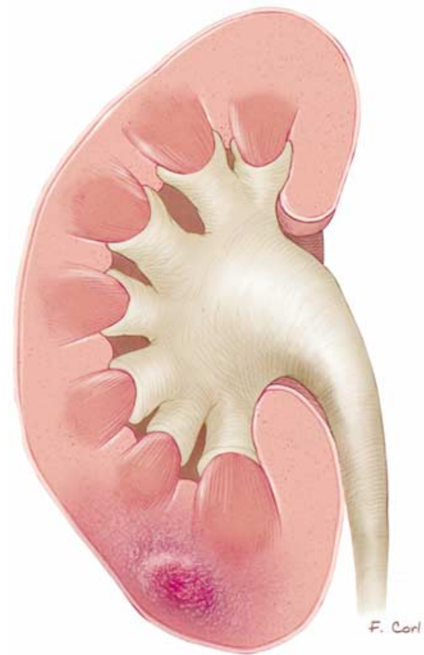


Figure 2. Drawing illustrates a focal intrarenal hematoma.

Retrograde Pyelography

Retrograde pyelography is valuable in the assessment of ureteral and renal pelvic integrity when ureteropelvic junction injury is suspected. However, it is not helpful in evaluating renal parenchymal injuries.

Ultrasonography

US is well accepted as a method for detecting hemoperitoneum in patients with suspected intraperitoneal injuries following blunt trauma but is limited compared with CT in the evaluation of the renal parenchyma. In one recent study comparing US with CT in this setting, several renal injuries were missed at trauma US (20).

Radionuclide Renal Scintigraphy

Occasionally, radionuclide renal scintigraphy may be helpful in documenting the presence of a functioning kidney in patients with a contraindication for iodinated contrast material or in following up repair of renovascular trauma (21). Renal scintigraphy can be performed with technetium (Tc)–99m glucoheptonate, Tc-99m mercaptoacetyltriglycine, or Tc-99m diethylenetriamine pentaacetic acid (22–24).

MR Imaging

MR imaging may be used to assess suspected renal injury when there is a contraindication for iodinated contrast material or when CT is not available (25). Like contrast-enhanced CT, MR imaging with use of intravenous gadolinium-based contrast material has proved helpful in the assessment of urinary extravasation (26).

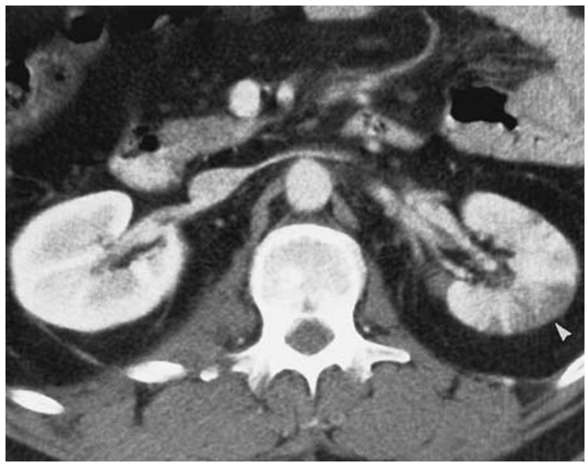


Figure 3. Renal contusion (category I) in a 46-year-old man who had sustained blunt abdominal trauma. Contrast-enhanced nephrographic-phase helical CT scan demonstrates a focal area of decreased contrast enhancement in the interpolar region of the left kidney (arrowhead).

Radiologic Classification of Renal Injuries

Renal injuries can be classified into four large categories as shown in the Table.

Category I

Minor injuries include renal contusions, subcapsular hematomas, minor lacerations with limited perinephric hematoma without extension to the collecting system or medulla, and small cortical infarcts. Category I renal injuries constitute 75%–85% of all renal injuries in most series and are generally managed conservatively (3,27).

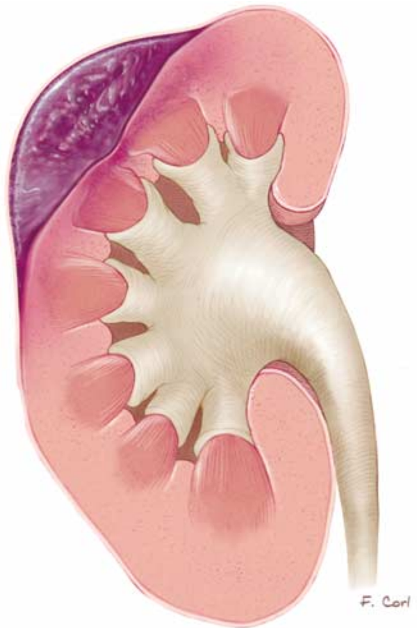


Figure 4. Drawing illustrates a subcapsular hematoma.

Figure 5. Subcapsular hematoma (category I) in a 40-year-old man who had sustained blunt abdominal trauma. Contrast-enhanced helical CT scan demonstrates a subcapsular fluid collection (straight white arrows) flattening the posterolateral contour of the left kidney. There is minimal cortical laceration (black arrow). Note also the subcutaneous emphysema in the left side of the back (curved arrow). A chest tube had been inserted for a left pneumothorax (not shown).

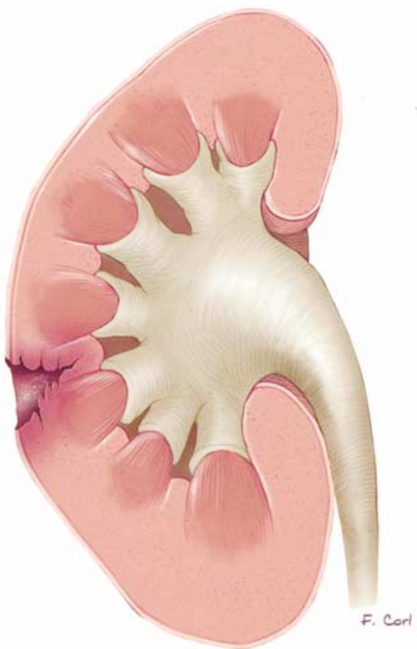


Figure 6. Drawing illustrates a small cortical laceration.

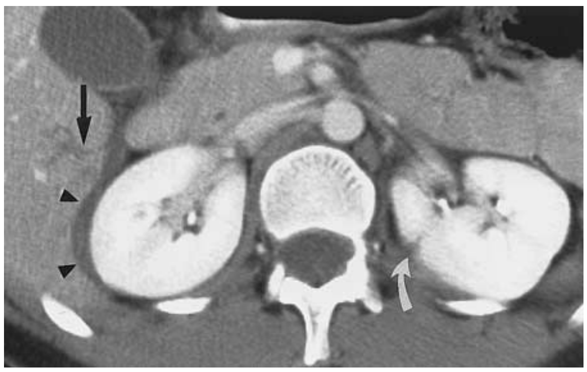


Figure 7. Simple renal laceration (category I) in a 30-year-old woman who had sustained blunt abdominal trauma. Contrast-enhanced multidetector helical CT scan reveals a small, hypoattenuating laceration crossing the interpolar region of the left kidney (white arrow) associated with a limited perinephric hematoma. A hepatic laceration (black arrow) and hemoperitoneum in the Morrison pouch (arrowheads) are also seen.

The vast majority of minor injuries represent small intrarenal hematomas (renal contusions), which may appear as ill-defined, round or ovoid hypoattenuating areas at CT (Figs 2, 3). They may also appear as focal areas of striation on delayed nephrograms or persistent contrast material staining on nephrograms obtained after even greater delay. A subcapsular hematoma appears as a round or elliptic hyperattenuating fluid collection indenting or flattening the renal margin (Figs 4, 5). Occasionally, hematoma between the renal capsule and the renorenal septum in the perirenal space can appear identical to a subcapsular hematoma. High-attenuation fluid (40–70 HU; mean, 51 HU) is most consistent with acute clotted blood (15). Minor lacerations appear as defects in the periphery of the renal parenchyma without involvement of the collecting system (Figs 6, 7). A limited perinephric hematoma may be present. Subsegmental infarcts are increasingly recognized at CT and appear as small, sharply demarcated, wedge-shaped areas of decreased

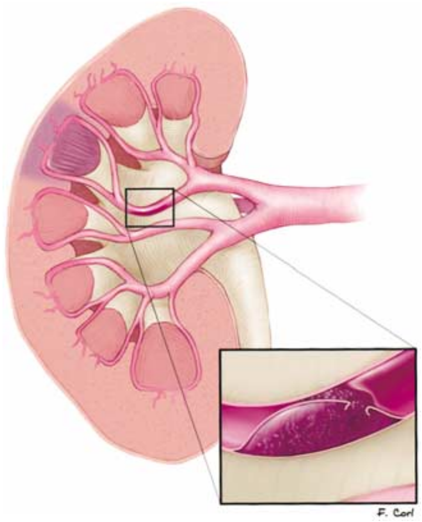


Figure 8. Drawings illustrate a segmental infarct.

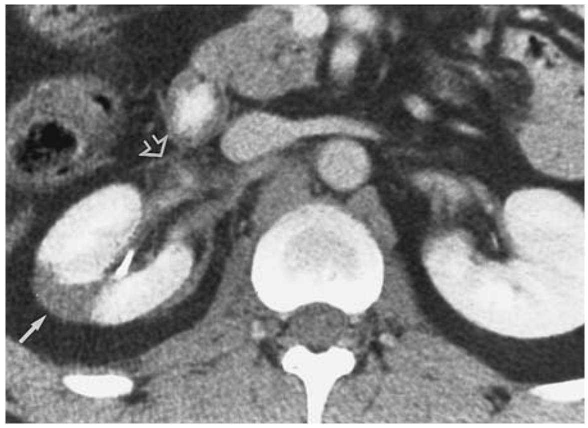


Figure 9. Subsegmental renal infarction (category I) in a 47-year-old man who had sustained blunt abdominal trauma. Contrast-enhanced CT scan demonstrates a sharply demarcated, wedge-shaped area of decreased attenuation in the interpolar region of the right kidney (solid arrow). Note also the evidence of subtle hemorrhage in the right renal hilum (open arrow).

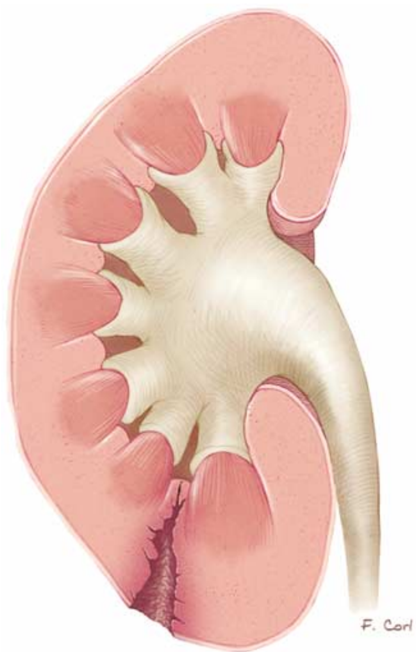


Figure 10. Drawing illustrates a laceration that extends to the medulla but does not involve the collecting system.

Figure 11. Major renal laceration without involvement of the collecting system (category II) in a 32-year-old woman who had sustained blunt abdominal trauma. Contrast-enhanced helical CT scan reveals a laceration in the posterolateral aspect of the middle portion of the left kidney (arrows) associated with perinephric hematoma. No urine extravasation was seen on excretory-phase scans (not shown).

contrast enhancement (Figs 8, 9), whereas renal contusions are not as well defined or sharply demarcated. Subsegmental infarcts are caused by stretching and thrombotic occlusion of an accessory renal artery, capsular artery, or intrarenal subsegmental branch. Subsegmental infarction results in a renal scar.

"Renal pseudofracture" appears as sharp indentation of the renal contour near the renal hilum and is created on CT scans by sectioning through the hilar lip of the kidney (28). The characteristic location of this "pseudofracture" and the absence of perirenal fluid allow proper diagnosis. "Pseudosubcapsular hematoma" appears as a region of decreased attenuation along the surface of the kidney caused by patient motion during data acquisition (28). The presence of similar findings in the anterior abdominal wall, liver, and contralateral kidney on the same image are clues to the diagnosis. This artifact is also confirmed when the region of low attenuation is not present on adjacent or repeat scans.

Category II

Lesions in category II comprise approximately 10% of renal injuries (27) and include major lacerations through the cortex extending to the me-

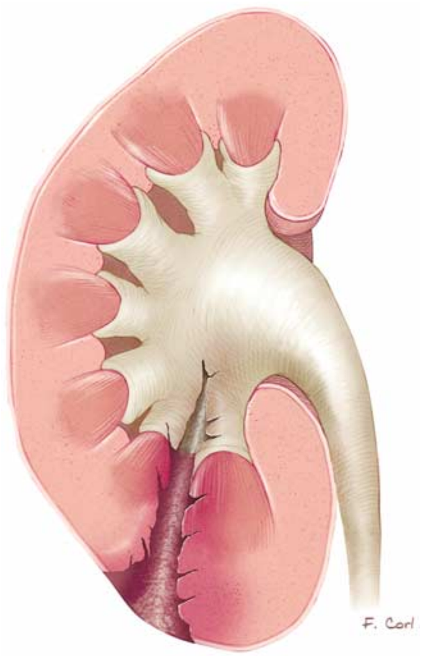


Figure 12. Drawing illustrates a deep parenchymal laceration involving the collecting system.

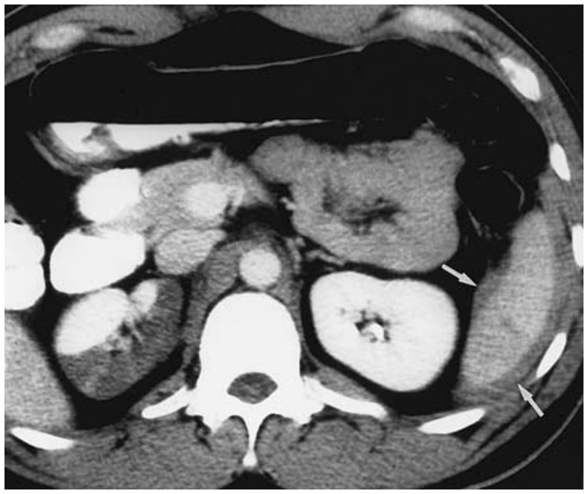
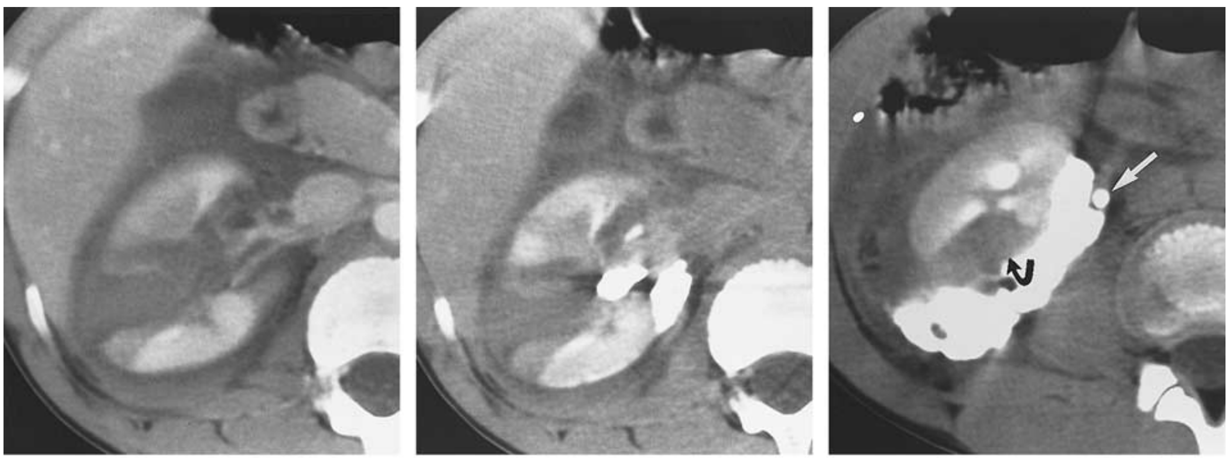


Figure 14. Segmental renal infarction (category II) in a 34-year-old man. Contrast-enhanced helical CT scan demonstrates a sharply demarcated area of decreased contrast enhancement in the posterior upper pole of the right kidney, a finding that is consistent with occlusion of the dorsal segmental branch of the renal artery. Note also the splenic laceration with perisplenic hematoma (arrows). (Reprinted, with permission, from reference 29.)



a. b. c.

Figure 13. Major renal laceration involving the collecting system (category II) in an 8-year-old boy who had sustained blunt abdominal trauma. **(a)** Contrast-enhanced nephrographic-phase CT scan shows a large, distracted renal fracture through the interpolar portion of the right kidney. **(b)** Contrast-enhanced excretory-phase CT scan shows extravasation of contrast material from a laceration of the renal pelvis into the medial perinephric space. **(c)** Delayed CT scan shows extensive extravasation around the lower pole of the right kidney. Note the antegrade filling of the ureter (white arrow). A small laceration is also seen in the lower pole (black arrow). (Fig 13 reprinted, with permission, from reference 19.)

dulla or collecting system with or without urinary extravasation. Major lacerations of the renal parenchyma appear as deep clefts that fill with hematoma with or without devascularized renal parenchyma and extend through the renal capsule associated with a perirenal hematoma (Figs 10, 11). When the laceration extends into the renal collecting system, extravasation of excreted contrast material will be present on delayed views (Figs 12, 13). Urine leakage due to a deep renal parenchymal laceration usually occurs into the lateral perinephric space.

Segmental infarcts appear as a sharply demarcated, dorsal or ventral segmental region of decreased enhancement of the parenchyma (Fig 14).

The management of category II lesions is variable. Affected patients are usually treated conservatively but occasionally require surgical

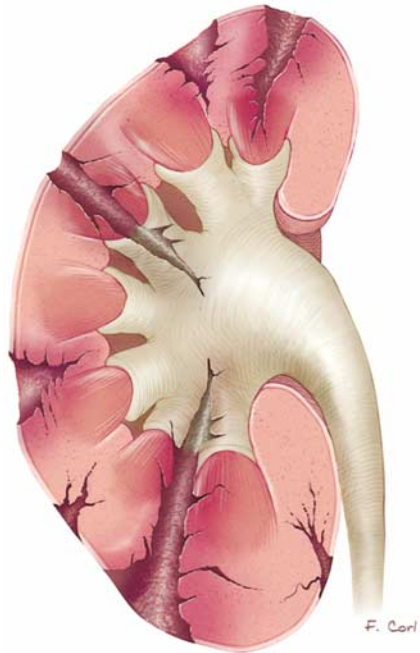


Figure 15. Drawing illustrates multiple renal lacerations.

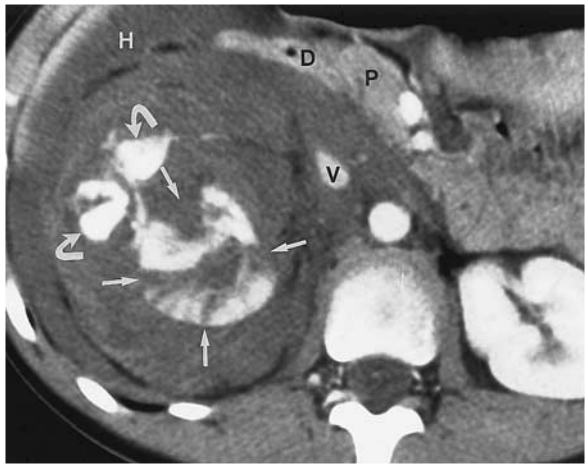
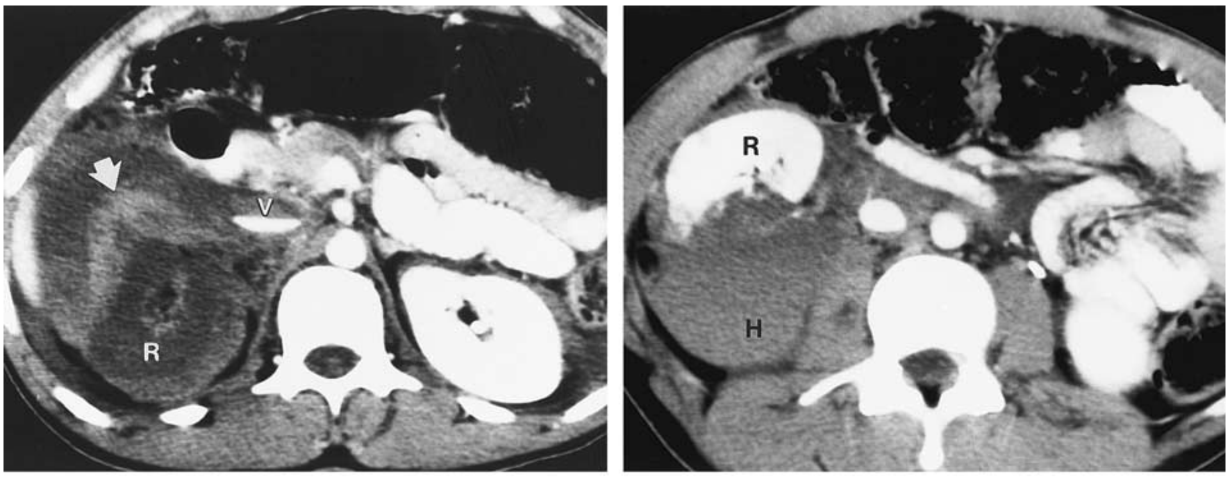


Figure 16. Multiple renal lacerations (category III) in a 9-year-old boy who had sustained blunt abdominal trauma and intraabdominal injury. Contrast-enhanced nephrographic-phase helical CT scan shows several deep lacerations of the interpolar region of the right kidney (straight arrows) associated with areas of active arterial extravasation (curved arrows). Note the anterior displacement of the duodenum (*D*), pancreas (*P*), and inferior vena cava (*V*). Hemoperitoneum (*H*) is seen in the Morrison pouch.



a. b.

Figure 17. Shattered kidney (category III) in a 28-year-old man who had sustained blunt abdominal trauma. **(a)** Contrast-enhanced helical CT scan demonstrates a devitalized upper pole of the right kidney due to segmental infarction (*R*). Note the perinephric hyperattenuating blood clot (arrow). Note also the flattened inferior vena cava (*V*), a finding that indicates hypovolemic shock. **(b)** CT scan obtained caudad to **a** demonstrates a large parenchymal laceration extending horizontally across the middle to lower pole of the right kidney (*R*), which is displaced anteriorly by a large, perinephric hematoma (*H*).

exploration depending on hemodynamic status and the evolution of the injury. For instance, a patient with an expanding perinephric hematoma and a decrease in hematocrit often requires intervention. Most urinary extravasation resolves spontaneously. However, a patient with impaired antegrade urine flow often requires surgical repair. Follow-up CT may be necessary to assess interval change in the appearance of the injury.

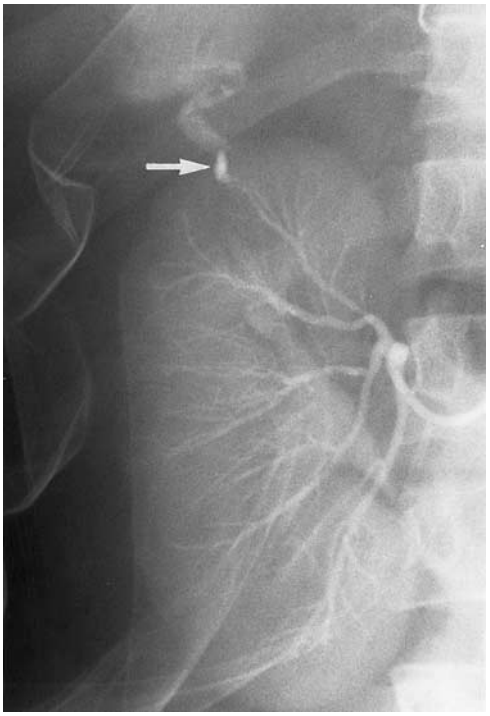


Figure 18. Active arterial extravasation (category III). Selective angiogram of the right main renal artery obtained following exploratory laparotomy demonstrates vascular extravasation from the upper pole of the right kidney (arrow). Intraarterial embolization was successfully performed to control bleeding.

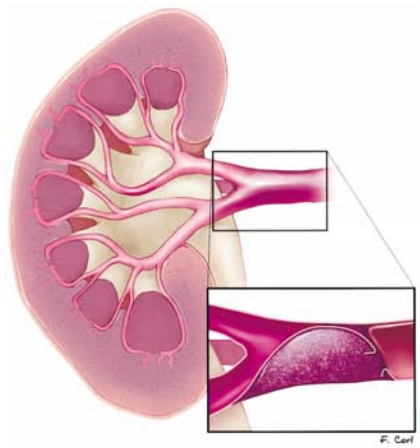


Figure 19. Drawings illustrate thrombosis of the main renal artery.

Category III

Lesions in category III are catastrophic injuries; they account for approximately 5% of cases and generally require surgical exploration, often nephrectomy (14). Category III injuries include multiple renal lacerations (Figs 15, 16) and vascular injuries involving the renal pedicle.

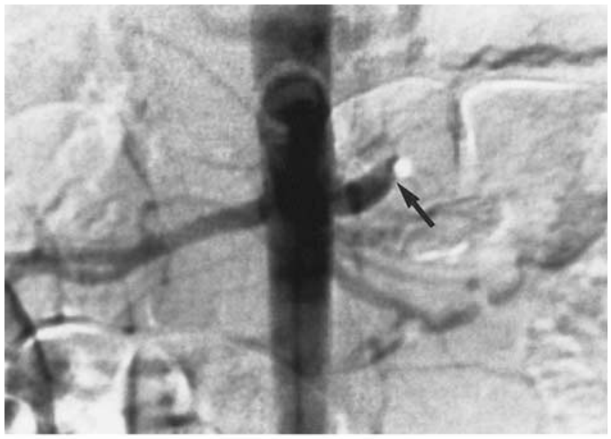
Multiple severe renal lacerations ("shattered kidney") are usually associated with one or more devitalized fragments, severe compromise in the excretion of contrast material, lacerations of the renal pelvis and collecting system, extensive hemorrhage, and active arterial bleeding (Figs 15–17). A devitalized segment due to a major laceration may not be appreciated at CT if it is surrounded by a hematoma. Active arterial extravasation appears as patchy areas of hyperattenuating contrast material (85–370 HU; mean, 132 HU) within a lower-attenuation hematoma that is best appreciated at dynamic contrast-enhanced CT (15). The presence of active arterial bleeding indicates a category III renal injury (14). Intraarterial embolization may be used to salvage the kidney (Fig 18).

The most significant vascular injury following blunt trauma is thrombosis of the main renal artery (29,30). Deceleration causes stretching and tearing of the intima, which is less elastic than the media and adventitia (31). The resultant intimal flap initiates thrombosis, which quickly propagates distally (31). Global infarction is less common than segmental or subsegmental infarction in patients who sustain blunt trauma. Nonvisualization of the kidney is consistent with thrombosis of the main renal artery (Figs 19, 20) but can also characterize other conditions including congenital or surgical absence of the kidney, renal ectopia, renal vascular spasm due to severe contusion, avulsion of the renal pedicle, and high-grade urinary obstruction. Contrast-enhanced helical CT

a.

b.

Figure 20. Traumatic occlusion of the main renal artery (category III) in a 17-year-old boy who had sustained blunt abdominal trauma. **(a)** Intravenous urogram demonstrates poor visualization of the left kidney. **(b)** CT scan obtained without additional contrast material following urography demonstrates rim enhancement of the outer cortex of the left kidney (arrows). **(c)** Digital subtraction aortogram demonstrates the characteristic tapered occlusion of the proximal left main renal artery (arrow).



c.

typically reveals an abrupt termination of the renal artery just beyond its origin and global renal infarction with or without the cortical rim sign (Fig 21) (32). The cortical rim sign usually appears several days after the initial injury (33) but has been reported to occur as early as 8 hours afterward (34). The absence of a perinephric hematoma is characteristic of a renal arterial occlusion, although a hematoma may be present around the proximal renal artery. In most cases, catheter angiography is not needed to confirm the CT diagnosis of renal artery thrombosis. A review of the literature showed that only five (14%) of 35 patients with unilateral posttraumatic occlusion of the renal artery who underwent revascularization had return of normal renal function; in all five patients, the duration of the ischemia was less than 12 hours (35). Nevertheless, revascularization may be attempted in patients with only one kidney or with bilateral renal arterial thrombosis (30,35).

Avulsion of the renal artery is a rare but life-threatening injury caused by tearing of the tunica muscularis and adventitia. CT reveals global in-

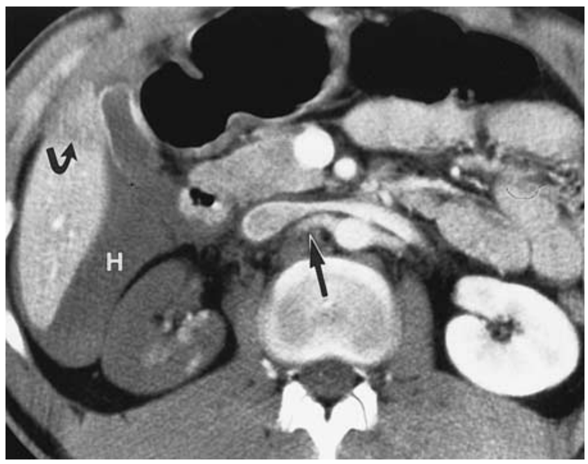
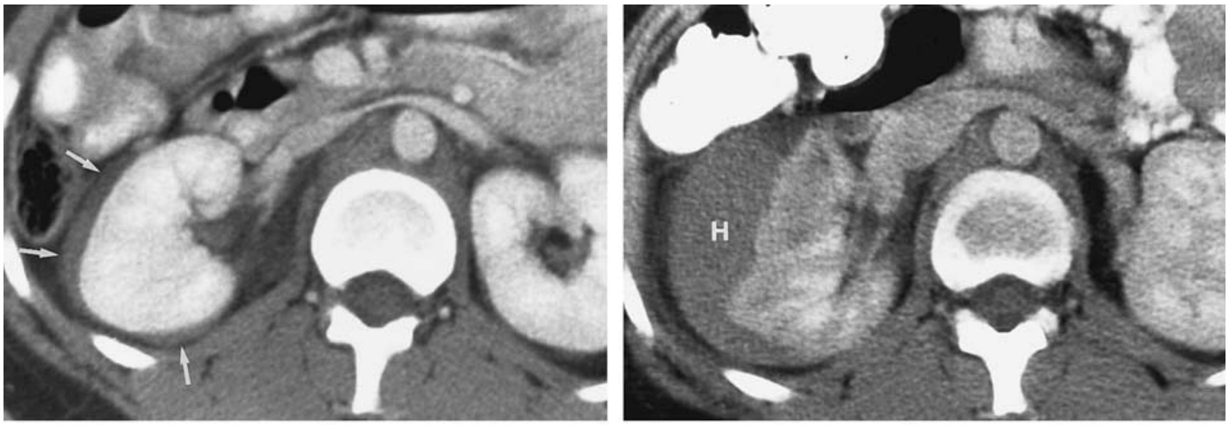


Figure 21. Traumatic occlusion of the main renal artery (category III) in a 38-year-old man who had sustained blunt abdominal trauma. Contrast-enhanced helical CT scan demonstrates a diminished right nephrogram. The proximal right renal artery (straight arrow) is enhanced; however, the distal main renal artery is not visualized. Note also the hepatic laceration (curved arrow) and hemoperitoneum in the Morrison pouch (*H*).



a. b.

Figure 22. Laceration of the renal vein (category III) in an 18-year-old woman who had sustained blunt abdominal trauma. **(a)** Contrast-enhanced helical CT scan demonstrates minimal perinephric hematoma without parenchymal laceration (arrows). **(b)** CT scan obtained 3 days later shows an interval increase in the amount of perinephric hematoma (*H*), resulting in deformation of the contour of the right kidney and a heterogeneously diminished nephrogram. The origin of the bleeding was not identified at CT. Laceration of the renal vein was found at surgery.

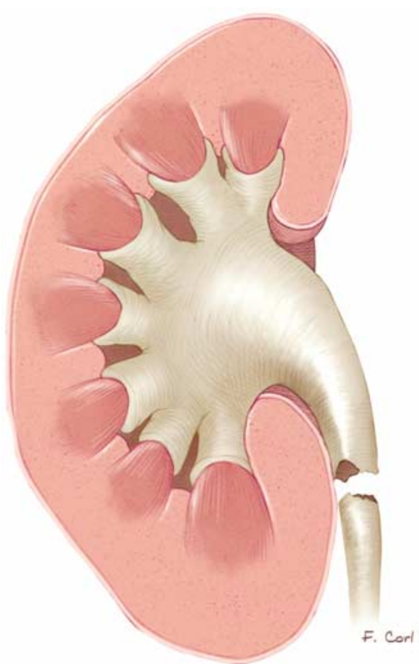


Figure 23. Drawing illustrates complete transection of the ureter.

farction of the kidney associated with extensive medial perirenal hematoma (28). Active arterial bleeding may also be seen.

Thrombosis or laceration of the renal vein is another rare form of renal pedicle injury (14,28, 36). Venography may be performed when injuries to the renal vein and inferior vena cava are suspected because CT may not reliably detect venous laceration (Fig 22) (1). Immediate surgical repair of venous injuries may be required to control bleeding. Isolated renal vein thrombosis is rare (36). Contrast-enhanced CT reveals an intraluminal thrombus in the distended renal vein and renal changes secondary to acute venous hypertension including nephromegaly, a diminished nephrogram, delayed nephrographic progression, and decreased excretion of contrast material into the collecting system (36).

Category IV

Ureteropelvic junction injuries are a rare consequence of blunt trauma and are caused by sudden deceleration, which creates tension on the renal pedicle (37). The diagnosis may be delayed because hematuria is absent in one-third of patients (6). Intravenous urography and CT typically reveal excellent excretion of contrast material with an intact intrarenal collecting system but with medial perinephric urinary extravasation (19,38). A circumferential (circumrenal) urinoma may be seen around the affected kidney, but typically there is no perinephric hematoma. Ureteropelvic junction injuries are classified into two groups: avulsion (complete transection) (Figs 23, 24)

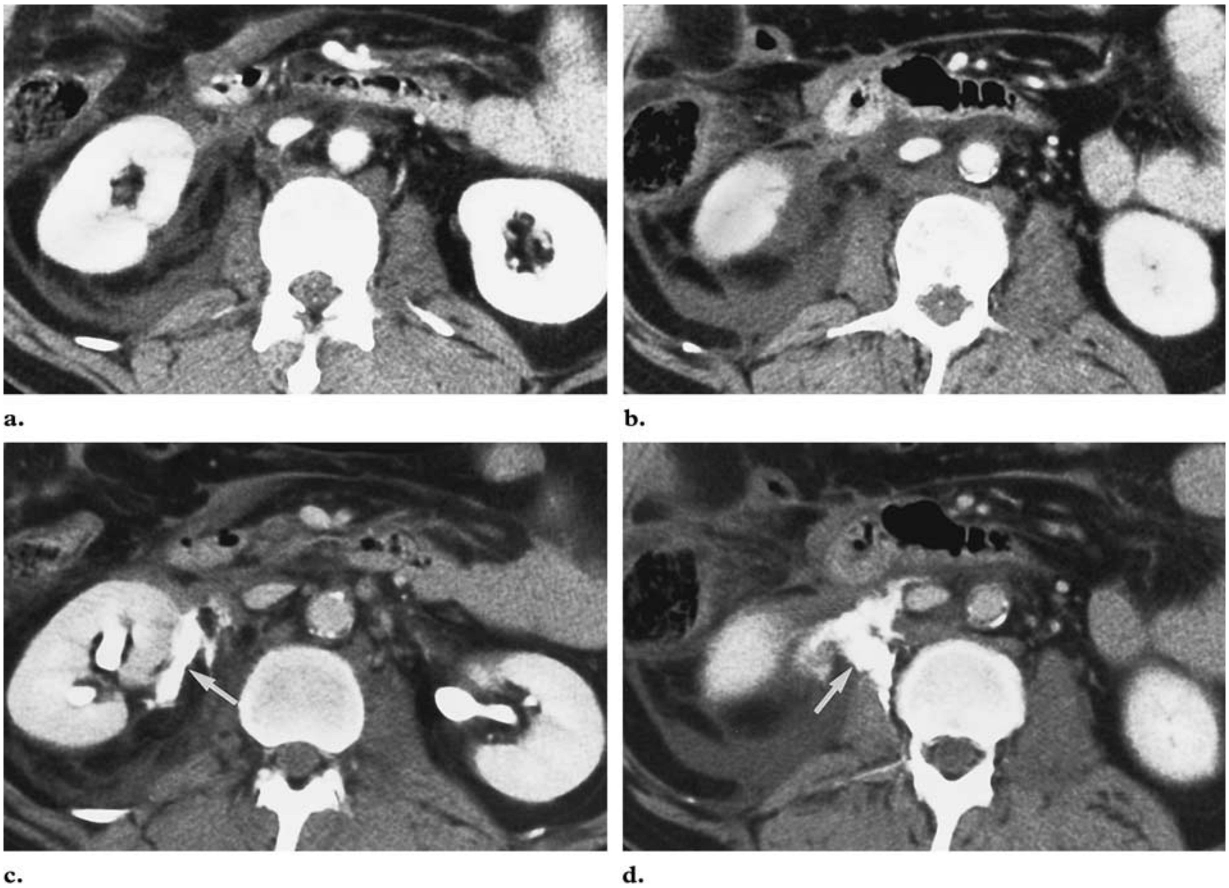


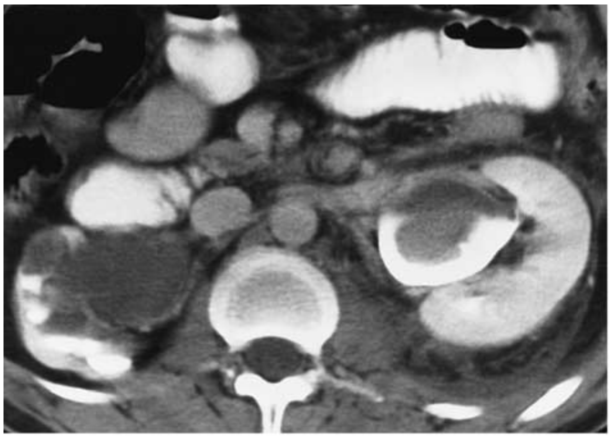
Figure 24. Avulsion of the ureteropelvic junction (category IV) in a 49-year-old man who had sustained blunt trauma. **(a, b)** Contrast-enhanced nephrographic-phase helical CT scans (**a** obtained at a higher level than **b**) through the lower pole of the right kidney demonstrate a perinephric fluid collection with no renal laceration. **(c, d)** Contrast-enhanced excretory-phase CT scans (**c** obtained at a higher level than **d**) demonstrate medial contrast material extravasation (arrow). No ureteral contrast material filling is noted. The patient underwent exploratory laparotomy for a mesenteric laceration. A diagnosis of ureteropelvic junction avulsion was made, and primary surgical repair of the ureter was performed.

and laceration (incomplete tear) (Fig 25). The presence of contrast material in the ureter distal to the ureteropelvic junction helps differentiate laceration from avulsion. However, when neither CT nor intravenous urography unequivocally demonstrates ipsilateral ureteral filling, retrograde pyelography should be performed. Ureteropelvic junction avulsion is usually treated with surgical repair, whereas laceration may be treated conservatively or with stent placement.

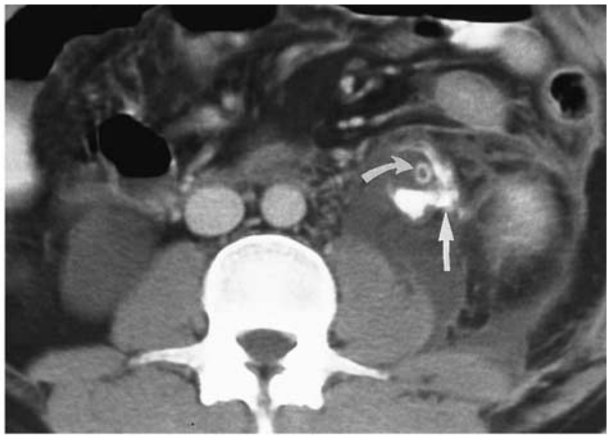
Pyelosinus contrast material extravasation following blunt trauma has rarely been reported and can be differentiated from ureteropelvic junction injury at excretory urography (39). It typically resolves quickly, unlike extravasation caused by more significant renal injuries. Patients with posttraumatic pyelosinus contrast material extravasation do not require urologic intervention.

Penetrating Injuries

In a study by Sagalowsky et al published in 1983 (2), all 122 patients with renal injuries from anterior gunshot wounds had associated intraabdominal injuries at surgery. Stab wounds less frequently have associated intraabdominal injury, with reported prevalence ranging from 30% to 70% (2,40). In patients with a stab wound limited to the flank and back, contrast-enhanced CT can be used to assess the extent of injury and to potentially obviate surgical exploration (Fig 26) (41). CT is not usually performed in patients with an anterior stab wound because these patients generally require exploratory laparotomy due to the high prevalence of bowel injury associated with this form of trauma.



a.



b.

c.

Figure 25. Ureteropelvic junction laceration with preexisting obstruction (category IV) in a 27-year-old man who had sustained blunt abdominal trauma. **(a)** Contrast-enhanced excretory-phase CT scan demonstrates left-sided pelviectasis and right-sided pelvocaliectasis. A large blood clot is present in the left renal pelvis. **(b)** Axial CT scan obtained inferior to the lower pole of the left kidney shows contrast material extravasation at the point of laceration of the ureteropelvic junction (straight arrow). A periureteral urinoma is also present. The enhanced ureter contains a filling defect (curved arrow), presumably secondary to a blood clot. **(c)** Intravenous urogram shows medial perinephric contrast material extravasation on the left side with a normal-caliber ureter distally (arrows), findings that indicate that ureteral continuity has been maintained. Pelvocaliectasis is also present, a finding that is consistent with bilateral ureteropelvic junction obstruction. (Reprinted, with permission, from reference 19.)

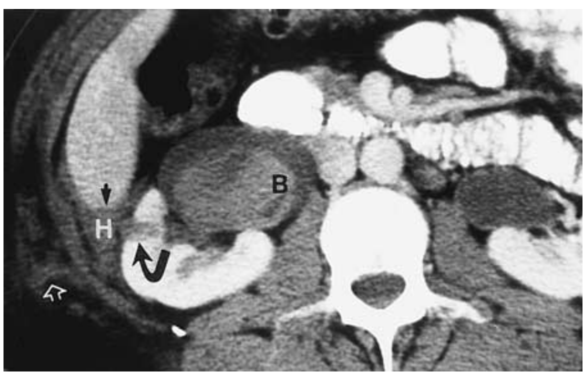
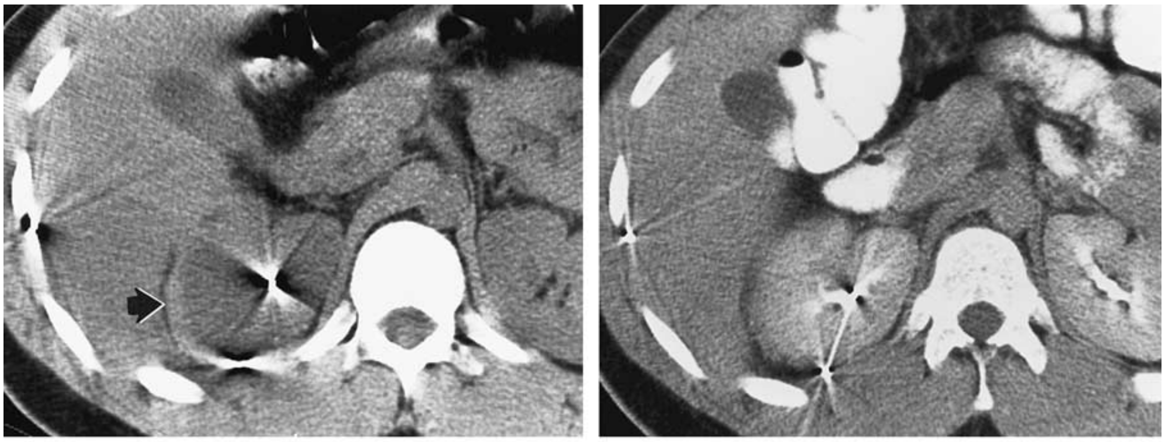


Figure 26. Renal laceration in a 25-year-old man who had sustained a stab wound to the right posterolateral aspect of the abdomen. Contrast-enhanced nephrographic-phase helical CT scan reveals laceration of the anterolateral aspect of the right kidney (curved arrow) with a blood clot in a right extrarenal pelvis (*B*). Note the small hepatic laceration (straight black arrow) and minimal hemoperitoneum (*H*). The stab wound is seen in the abdominal wall (white arrow). An extrarenal pelvis is also present on the left side.

a.



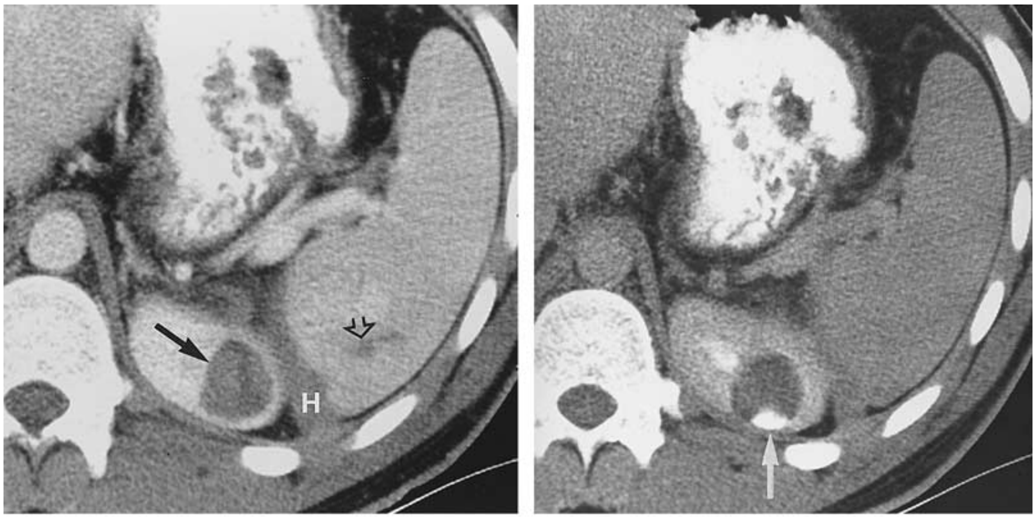
b. c.

Figure 27. Renal injury in a 20-year-old man who had sustained a gunshot wound. **(a)** Conventional radiograph of the right upper quadrant of the abdomen shows multiple pellets. **(b)** Unenhanced CT scan reveals a pellet in the upper pole of the right kidney. Note the minimal perinephric hematoma (arrow). **(c)** On a contrast-enhanced excretory-phase helical CT scan, the pellet is seen in proximity to the collecting system. Retained pellets may potentially migrate into the collecting system and result in ureteral obstruction ("buckshot colic").

Ureteral obstruction caused by intramural missiles or migrating retained missiles in shotgun, gunshot, or shrapnel wounds ("bullet colic," "buckshot colic," "birdshot calculus") is an unusual complication of penetrating injuries to the abdomen (42,43). Bullet colic involving bullets and shrapnel fragments usually involves long latent periods after initial injury and often requires surgery to remove the obstructing projectile (43). In contrast, buckshot colic from shotgun pellets manifests earlier and often resolves with spontaneous passage of the pellets (43). Excretory urography and CT are useful for investigation (Fig 27).

Traumatic Injuries to Kidneys with Preexisting Abnormalities

A kidney with a preexisting abnormality is at increased risk for injury (23). An underlying renal disorder may be first brought to medical attention because the severity of the patient's symptoms is disproportionate to the degree of injury suffered. 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 or an extrarenal pelvis (Fig 25), intracystic hemorrhage or rupture of a renal cyst with or without communication with the collecting system (Figs 28, 29), rupture of a tumor, laceration of poorly protected ectopic or horseshoe kidneys (Fig 30), and laceration of fragile, infected kidneys. CT provides more specific and clinically useful information than excretory urography in this context (44).



a. b.

Figure 28. Renal cyst complicated by intracystic hemorrhage with communication with the collecting system in a 23-year-old man who had sustained blunt abdominal trauma. **(a)** Contrast-enhanced nephrographic-phase helical CT scan shows a cyst with hyperattenuating fluid in the upper pole of the left kidney (solid arrow), findings that are consistent with intracystic hemorrhage. Note the splenic laceration (open arrow) and perisplenic hematoma (*H*). **(b)** Contrast-enhanced excretory-phase CT scan demonstrates contrast material in the cyst (arrow).

Figure 29. Rupture of a renal cyst in a 71-year-old man who had sustained blunt abdominal trauma. Contrast-enhanced helical CT scan demonstrates a cyst with a fluid-fluid level in the midpolar region of the left kidney (straight solid arrow) with a perinephric fluid collection (curved arrow). Note the thickening of the renal fascia (open arrow).

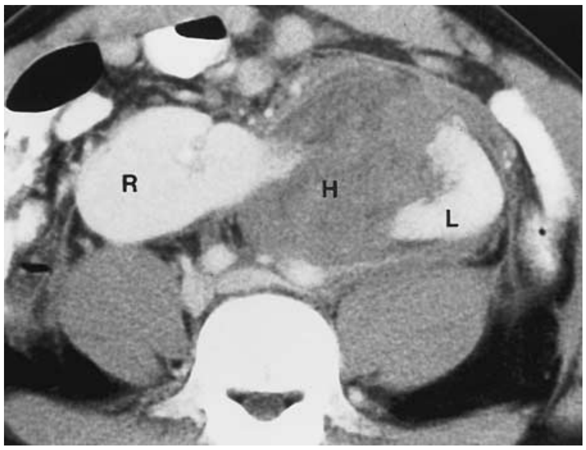


Figure 30. Renal injury in a 33-year-old man with a horseshoe kidney. Contrast-enhanced helical CT scan demonstrates a large renal laceration through the isthmus of a horseshoe kidney associated with perinephric hematoma (*H*). *L* = left kidney, *R* = right kidney. (Courtesy of Stephen Karasick, MD, Department of Radiology, Thomas Jefferson University Hospital, Philadelphia, Pa.)

Urologic Complications in Renal Injury

Early complications occur within 4 weeks of injury and include urinary extravasation and urinoma formation, delayed bleeding, infected urinoma, perinephric abscess, sepsis, arteriovenous fistula, pseudoaneurysm (Fig 31), and hypertension (1). Late complications include hydronephrosis, hypertension, calculus formation, and chronic pyelonephritis (1). In a study performed to define the outcome of major blunt renal injuries with nonsurgical versus surgical treatment, Husmann and Morris (45) found that delayed urologic complications occur more frequently in patients with a devascularized fragment than in those with vascularized fragments. Infected urinomas and perinephric abscesses frequently occur in patients with an unrepaired, devitalized renal segment and concomitant injury to the pancreas or bowel (46).

Posttraumatic renovascular hypertension is an uncommon complication of renal injury whose precise prevalence is difficult to establish. Possible mechanisms for the development of posttraumatic hypertension include renal artery occlusion, renal artery stenosis with or without an intimal flap, renal artery compression, severe renal contusion, arteriovenous fistula or pseudoaneurysm formation, and a chronic contained subcapsular hematoma (47). In a study by Cass and Luxenberg (48), hypertension occurred in only 10 (6%) of 170 reported cases of traumatic thrombosis of segmental renal arteries. The majority of patients who develop hypertension following segmental arterial thrombosis can be treated nonsurgically unless there is cardiovascular instability (49). Ten patients with documented traumatic injuries to a branch renal artery were followed up for 1 to 5 years; in two (20%) of these patients, hypertension developed immediately after injury but resolved spontaneously within 1 year (49). In a recent review of seven patients who suffered hypertension 2 weeks to 8 months following blunt trauma, selective angiograms showed occlusion of the main renal artery in two patients, significant stenosis from an intimal flap in one, severe renal contusion in two, and segmental renal arterial branch injuries in two (50). Arteriovenous fistula and pseudoaneurysms as a result of deep renal laceration can also produce renin-mediated hypertension. A chronic contained subcapsular hematoma (Fig 32) and perirenal scarring may rarely create a compressive force on the deformed kidney, reducing flow to the kidney and inducing renin-mediated hypertension (Page kidney).

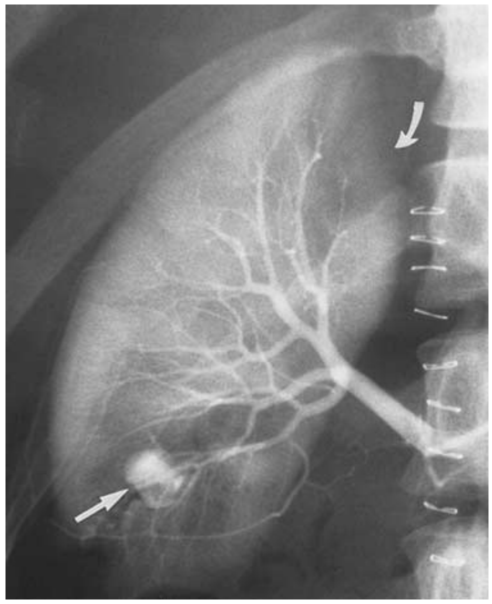


Figure 31. Pseudoaneurysm in a patient who had sustained a stab wound and had undergone exploratory laparotomy. Selective arterial-phase right renal angiogram demonstrates a false aneurysm in the lower pole of the right kidney (straight arrow). Subsegmental infarction is noted in the upper pole (curved arrow). Bleeding was controlled with intraarterial embolization. Surgical staples from the laparotomy are seen at the midline.

Selective renal angiography and renin sampling may be preferred for the evaluation of patients with suspected renovascular hypertension, although dynamic contrast-enhanced CT with angiographic techniques can reveal vascular lesions. Page kidney may appear as a subcapsular fluid collection or perirenal soft-tissue thickening and as a delayed nephrographic progression in the affected kidney compared with the contralateral kidney. Percutaneous drainage of a chronic subcapsular hematoma may be performed.

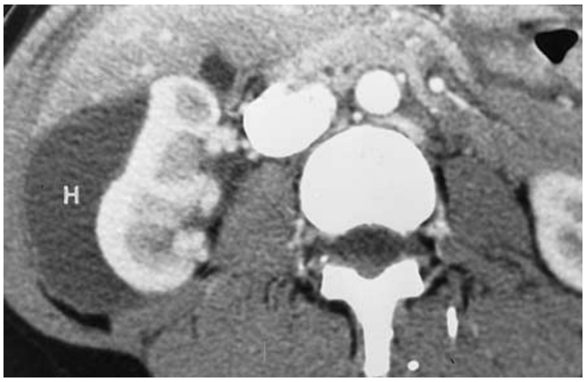


Figure 32. Subcapsular hematoma (Page kidney) in a 30-year-old woman with a history of a seizure disorder who presented with right flank pain and hypertension. Contrast-enhanced spiral CT scan demonstrates a subcapsular fluid collection (*H*) flattening the right kidney. The patient underwent successful US-guided percutaneous drainage of the hematoma.

Conclusions

CT plays a major role in assessing patients with renal injuries. Understanding the radiologic classification of traumatic renal injuries is helpful in patient triage. The imaging findings in renal injury should be integrated with clinical information to assist in developing a treatment plan.

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