Kidney in Danger: CT Findings of Blunt and Penetrating Renal Trauma[1]

CME FEATURE

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

LEARNING OBJECTIVES FOR TEST 3

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

- Describe the mechanism of renal injuries, clinical features, and indications for imaging in renal trauma.
- Identify the distinguishing CT features of renal trauma according to the AAST grading system.
- Discuss the treatment of patients with renal trauma, with emphasis on the role of nonsurgical treatment and minimally invasive techniques in the management of active bleeding.

TEACHING POINTS

See last page

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Approximately 10% of all significant blunt abdominal traumatic injuries manifest with renal injury, although it is usually minor. However, renal imaging is indicated in cases of gross hematuria, penetrating trauma with gross or microscopic hematuria, and blunt trauma and shock with gross or microscopic hematuria. Contrast material–enhanced computed tomography (CT) is the imaging modality of choice in the evaluation and management of renal trauma. Contrast-enhanced CT is readily available in emergency departments and can quickly and accurately depict renal injuries as well as associated injuries to other abdominal or retroperitoneal organs. In this way, contrast-enhanced CT provides the anatomic and functional information that is essential for accurate staging. In addition, CT can help detect active hemorrhage and urinary extravasation and is very useful in guiding transcatheter embolization and delineating preexisting disease entities that may predispose kidneys to posttraumatic hemorrhage. With the advent of multidetector CT, imaging is characterized by faster scanning times, increased volume coverage, and improved spatial and temporal resolution. The increased use of CT has been partially responsible for a growing trend toward conservative management of renal trauma, except in cases in which extensive urinary extravasation or devitalized areas of renal parenchyma are found and especially in those cases with associated injuries to other abdominal organs; these cases are particularly prone to complications and usually require surgery.

Abbreviations: AAST = American Association for the Surgery of Trauma, FAST = focused assessment with sonography for trauma, MPR = multiplanar reformation

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Introduction

Urinary tract injuries occur in 3%–10% of all abdominal trauma patients, the kidney being the most commonly injured organ (1–10). The vast majority (80%–90%) of cases are secondary to blunt abdominal trauma (2,7,11), and most significant renal trauma is associated with injury to other major organs (2,3). On the other hand, up to 95%–98% of isolated renal injuries are considered minor injuries and are managed nonsurgically because they usually heal spontaneously without complications (2,4,9–17).

Contrast material–enhanced computed tomography (CT) is the imaging technique of choice for the evaluation of renal trauma, since it is widely available in emergency units and can quickly and accurately demonstrate not only injuries involving the kidney, but also associated damage to other abdominal or retroperitoneal organs (1–5,12,18,19).

Active bleeding is easily depicted at multidetector CT but is not explicitly included in the American Association for the Surgery of Trauma (AAST) classification system, which is based on the appearance of the kidney at surgery.

In this article, we describe the mechanisms and clinical features of renal injury, indications for genitourinary imaging, and imaging techniques and protocol. In addition, we discuss and illustrate the spectrum of CT findings of blunt and penetrating renal trauma according to the AAST renal injury scale. We also discuss traumatic injuries to kidneys with preexisting abnormalities; iatrogenic renal trauma; complications of renal trauma; and various management options, with emphasis on the increasing role of nonsurgical treatment for a variety of renal injury patterns and the use of multidetector CT and angiographic techniques.

Mechanism of Renal Injuries

The kidneys are anatomically protected from damage by the surrounding ribs, muscles (psoas and quadratus lumborum muscles), perinephric fat, and peritoneum (1,18). Despite this protection, however, damage to the urinary tract is relatively common in cases of significant blunt or penetrating abdominal trauma.

Renal injury is usually the result of trauma to the back, flank, lower thorax, or upper abdomen and may be divided into two basic categories: blunt trauma and penetrating trauma. Blunt renal trauma accounts for up to 80%–90% of all cases, with motor vehicle accidents being the most common cause; less common causes include *(a)* a direct blow to the flank or abdomen during an assault, a fight, or a sports activity (eg, bicycling, horseback riding); and *(b)* a fall from a height. All of these causes result in sudden deceleration or crush injuries that may affect the renal parenchyma or the vascular pedicle (1,2,5–8,10,11).

Teaching Point

Penetrating trauma accounts for approximately 10% of all renal injuries (1) and is almost always caused by gunshot or stab wounds, except for the few iatrogenic injuries resulting from renal biopsy or other medical procedures (7,10,18,20). The lesional mechanism consists of direct damage to the parenchyma, excretory system, or vascular structures and even violation of the peritoneum. Penetrating injuries are often associated with a nonsterile condition, with increased risk of bacterial growth within the hematoma or urine leakage that may require surgical débridement or even nephrectomy (7,11,18,20,21).

Gunshot wounds have a specific mechanism of injury known as the "blast" effect, which produces cavitation within the tissues and may cause delayed necrosis of previously healthy tissue. The crushing of the tissue that is struck by the bullet (permanent cavity) and the stretching of the surrounding tissue (temporary cavity) are the wounding mechanisms. The size of the temporary cavity depends on the velocity of the bullet and the amounts of collagen and elastin in the tissue (1,20,22).

Clinical Features of Renal Trauma and Indications for Genitourinary Imaging

Most significant renal injuries (95%) manifest with hematuria, with gross hematuria generally being associated with more severe renal trauma (1–3,11). Only 0.1%–0.5% of hemodynamically stable patients who present with microscopic hematuria have significant urinary tract injuries; therefore, microscopic hematuria is not in itself an absolute indication for renal imaging (3,6,10,13,18,19). Moreover, it is now widely accepted that no significant urinary tract injury occurs in the absence of gross hematuria and shock in an adult patient (18).

On the other hand, hematuria may be absent when ureteral tear, vascular pedicle injury, or ureteropelvic junction avulsion occurs. In such cases, there is no direct relationship between the degree of hematuria and the extent of renal injury (1,3,6,10,11,18).

Teaching Point

Although the increased use of CT for the evaluation of blunt trauma has lessened the need for specific indications for renal evaluation (18), universally accepted indications for renal imaging in blunt trauma include *(a)* gross hematuria; *(b)* microscopic hematuria and hypotension (systolic blood pressure <90 mm Hg) or other associated injuries requiring CT evaluation; and *(c)* blunt trauma with other injuries known to be associated with renal injury (eg, rapid deceleration, fall from a height, direct contusion or hematoma of flank soft tissues, fractures of the lower ribs or thoracolumbar spine), regardless of the presence of hematuria (1–3,5,6,10–13,18,19,23–26). In all patients who sustain penetrating injury to the abdomen, flank, or lower thorax, the possibility of sustained renal injury must be considered. Any degree of hematuria warrants renal imaging because most penetrating renal injuries are associated with injuries to other organs, except in hemodynamically unstable patients who require immediate surgery. Equally important, the absence of hematuria after penetrating trauma does not rule out the possibility of renal injury, since major renal vascular lacerations may occur without hematuria.

Imaging Techniques

Conventional radiography is an important tool in the primary evaluation of chest and skeletal trauma; however, it is almost never used in the setting of blunt abdominal trauma (3). Intravenous urography, retrograde urethrography, and cystography have traditionally been used to assess genitourinary trauma—although normal or nonspecific imaging findings often required complementary techniques (1–3)—but the wide availability of CT as a primary imaging modality in major trauma patients has reduced the use of these imaging modalities. The primary role of intravenous urography is to assess gross renal function in patients who are too unstable to undergo CT and are already in the operating room (1–3,8–11,18,19,27). In the emergency setting, the most frequently used radiologic techniques are ultrasonography (US), CT, and angiography.

Focused Assessment with Sonography for Trauma

US has well-known advantages in the evaluation of major trauma, including minimal preparation time, low cost, wide availability, portability, and noninvasiveness (1,28,29).

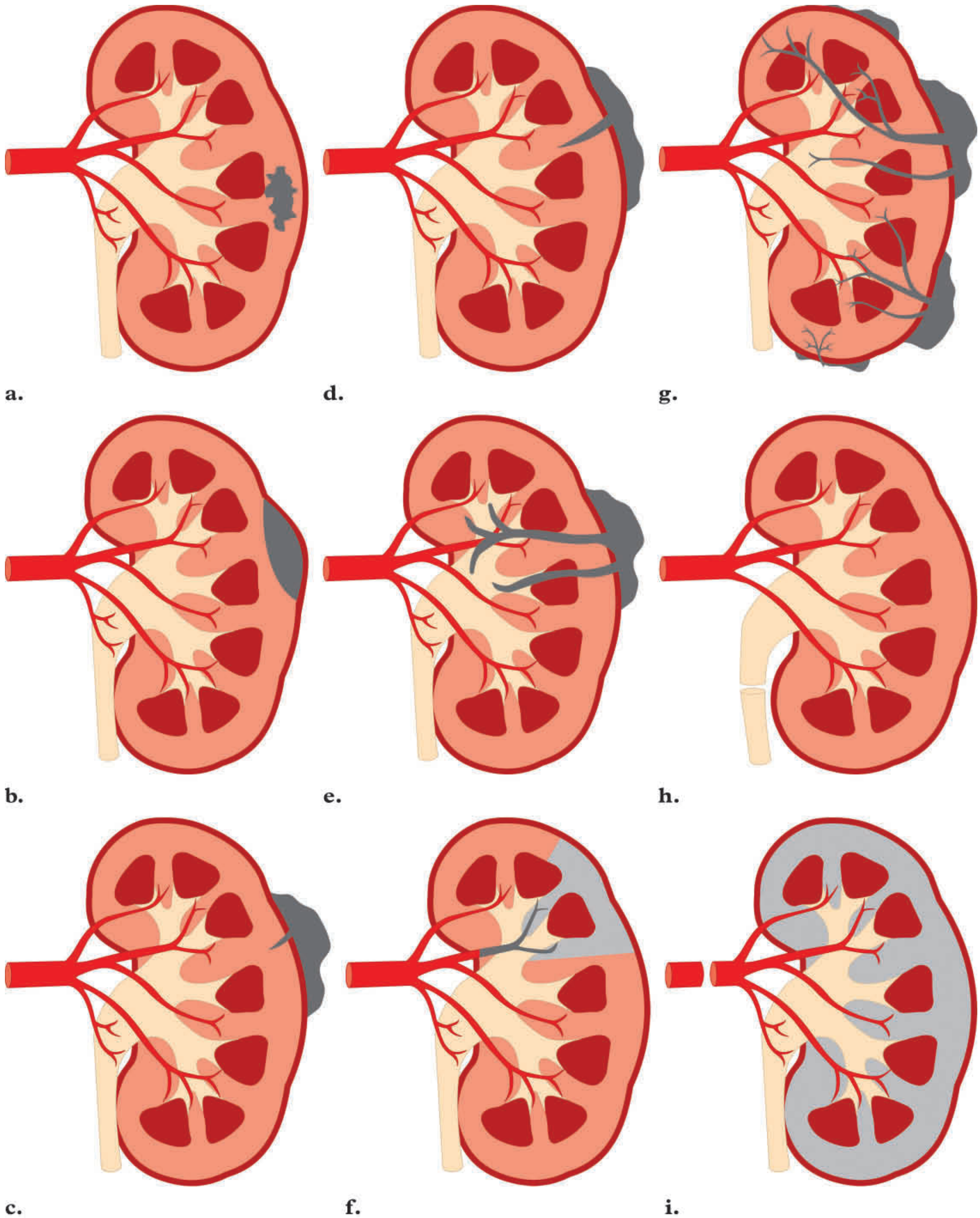
The primary goal of focused assessment with sonography for trauma (FAST) is to identify intraabdominal free fluid, which is considered to be synonymous with hemoperitoneum in unstable patients (1,2,18,28–31). When free fluid is found, associated solid organ injury is present in up to 80%–90% of cases.

On the other hand, US also has some disadvantages. It cannot reliably help differentiate blood from extravasated urine or other body fluids (3,6,11), cannot help assess renal function, is operator dependent (11,18,29), and has a low sensitivity (44%–95%) for the detection of retroperitoneal blood, retroperitoneal injury, or injury to solid organs or hollow viscera (1,3,28–32). Moreover, even when solid organ injuries are detected, US often leads to underestimation of injury severity. Several studies have reported the sensitivity of US for the detection of renal lesions to be as low as 22% (3,28). For this reason, negative US findings do not exclude renal injury, and, depending on clinical and laboratory findings, other imaging modalities such as CT should be performed to detect and stage specific renal injuries (30,31).

The role of FAST in blunt abdominal trauma can be summarized as follows: *(a)* hemodynamic instability in patients with positive FAST results warrants surgical exploration, whereas indeterminate FAST results lead to a complete repeat US or CT examination; *(b)* hemodynamically stable patients with positive or indeterminate FAST results should undergo CT examination; and *(c)* hemodynamically stable patients with negative FAST results may be followed up with clinical observation of at least 6 hours duration and with repeat FAST or a complete US examination to confirm the absence of injury (1,3,11,28–32). Nevertheless, there is no consensus about the indications for repeat US, the intervals at which it should be performed, or the number of negative results needed for safe discharge of the patient; thus, CT may still be indicated.

Angiography

Angiography is seldom used anymore for the initial diagnosis of suspected renal artery injuries since the advent of multidetector CT, which allows quick and accurate detection of vascular pedicle injuries and intravenous contrast material extravasations (1–3,8,19,33). Because acute occlusion



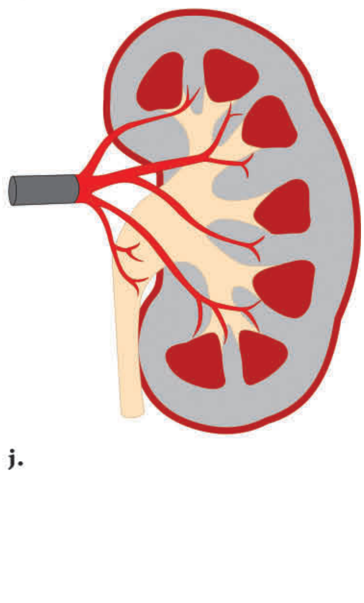


Figure 1. Drawings illustrate the AAST grading system for renal injury: grade I, contusion **(a)**; grade I, subcapsular hematoma **(b)**; grade II, renal laceration **(c)**; grade III, renal laceration **(d)**; grade IV, renal laceration involving the collecting system **(e)**; grade IV, segmental infarction without associated lacerations **(f)**; grade V, shattered kidney **(g)**; grade V, ureteropelvic junction avulsion **(h)**; grade V, avulsion of the main renal artery **(i)**; and grade V, thrombosis of the main renal artery **(j)**.

of the main renal artery is poorly tolerated by the kidney and revascularization is uniformly unsuccessful unless attempted within the first few hours after injury, diagnostic delays must be minimized (33).

In contrast, angiography is increasingly being used in therapeutic applications, which may obviate surgery. Conservative (expectant) management of trauma cases is now widely accepted, so that angiography with transcatheter embolization is becoming the modality of choice for the treatment of active bleeding and secondary arterial hemorrhage, generally as a consequence of a posttraumatic pseudoaneurysm or arteriovenous fistula (1,3,8,10,18,19,34,35). Other generally accepted indications for renal arteriography are the evaluation of late complications such as hypertension and preoperative "mapping," since this modality provides precise information about the vascular anatomy (2,11).

Computed Tomography

Teaching Point

Since its advent in the mid-1980s, CT has clearly replaced intravenous urography and has become the imaging modality of choice for the evaluation of renal trauma and other associated injuries. CT provides, with short examination times, the essential anatomic and functional information necessary to determine the type and extent of parenchymal, vascular, or collecting system injuries and associated abdominal injuries (1–3,6,10,12,13,18,19,27). In addition, CT can help detect active hemorrhage and urine leakage and is of great help in guiding transcatheter embolization and delineating preexisting disease entities that may predispose to posttraumatic hemorrhage (13). The main advantages of multidetector CT over single-detector CT are faster scanning times, increased volume coverage, and improved spatial and temporal resolution.

Imaging Protocol

In the evaluation of renal trauma, the goal should be to obtain the largest amount of information in the shortest possible time. The best imaging approach may be dictated by local circumstances (18), and it is difficult to develop a universal imaging protocol that will work in all cases or even at all institutions; therefore, renal imaging in major trauma must be individualized and should be limited to the urinary tract or considered as part of a more general examination for suspected nonurologic injuries (11).

Whenever urinary tract injury is clinically suggested, it is necessary to perform a specially designed CT examination (5). For this purpose, an initial nonenhanced study can be helpful in detecting acute bleeding or intraparenchymal hematoma that may become isoattenuating relative to the normal renal parenchyma at postcontrast CT (25,36,37).

Intravenous contrast material should be administered to all patients to detect not only solid organ damage but also physiologic variants and vascular damage (1–3,11,12,18,23,36). The kidneys are generally evaluated as a part of CT protocol for major trauma, and routine CT usually includes a portal venous phase; therefore, the kidneys will be imaged during the late cortical or early nephrographic phase, which allows identification of parenchymal injuries (1,2,12,13,37).

Whenever vascular examination is necessary, bolus-tracking multiphase CT can be performed during the arterial and nephrographic phases. Selective use of 5-minute delayed CT of the abdomen and pelvis is recommended. Imaging should be performed during this phase to rule out leakage of contrast-enhanced urine if renal pedicle injury or significant perinephric or periureteral fluid is found, and whenever confusing findings requiring further characterization are depicted during the portal venous phase (1–3,6,12–14,23,25,27,37,38). Delayed CT may also be useful in distinguishing between active bleeding and pseudoaneurysms (38). Reducing the radiation dose may be adequate for making the diagnosis in most cases, since delayed CT is used primarily for the detection or characterization of contrast material, not intrinsic urinary tract lesions. Therefore, a decreased radiation dose is not likely to affect the diagnosis (14,38).

Spectrum of CT Findings

Several classification systems for renal injuries based on pathogenesis, morphologic features, and clinical parameters have been proposed in the literature. Nowadays, the most widely accepted and used classification system for renal injuries is the AAST grading system (1,2,18). This system is based on surgical findings (the standard for renal injury staging) (19) and has been validated as a useful tool for the prediction of clinical outcomes in patients with renal trauma (8–10,26). It includes five categories (grades I–V), arranged in order of increasing severity according to depth of injury and involvement of the vasculature or collecting system, and correlates well with any abnormalities detected at CT (Fig 1, Table) (1).

Teaching Point

AAST Renal Injury Scale

Grade*	Type of Injury	Description
I	Normal contusion	Microscopic or gross hematuria with normal urologic findings
	Hematoma	Nonexpanding subcapsular hematomas with no laceration
II	Hematoma	Nonexpanding perinephric (perirenal) hematomas confined to the retroperitoneum
	Laceration	Superficial cortical lacerations less than 1 cm in depth without collecting system injury
III	Laceration	Renal lacerations greater than 1 cm in depth without collecting system injury
IV	Laceration	Renal lacerations extending through the renal cortex, medulla, and collecting system
	Vascular injury†	Injuries involving the main renal artery or vein with contained hematoma, segmental infarctions without associated lacerations
V	Laceration	Shattered kidney, ureteropelvic junction avulsions
	Vascular injury	Complete laceration (avulsion) or thrombosis of the main renal artery or vein that devascularizes the kidney

*Advance one grade for bilateral injuries up to grade III.
†Some authors include expanding subcapsular hematomas that compress the kidney as grade IV injuries.

Grade I Injuries

Grade I injuries are the most common type of renal injury (75%–85% of cases) (1–6,14,19) and include hematuria (either microscopic or gross) with normal urologic findings, contusions, and nonexpanding subcapsular hematomas with no associated laceration (3).

Contusions are generally visualized as poorly marginated round or ovoid areas of decreased enhancement (Fig 2) and a delayed or persistent nephrogram compared with normal adjacent regions (1–6,12,14,19), although they may also have well-delineated margins and may even appear as hyperattenuating areas when blood clots fill the injured area, especially on precontrast images (1). Contusions should be differentiated from segmental infarctions, which are seen as well-delineated wedge-shaped areas that do not enhance after the intravenous administration of contrast material (1–3,11,12).

Nonexpanding subcapsular hematomas without parenchymal laceration are seen less frequently in blunt trauma than are perinephric hematomas (3). In the acute stage, they manifest as an eccentric, unenhanced, hyperattenuating fluid collection that is confined between the renal parenchyma and the renal capsule (Fig 3) (3–6). Thus, they are best appreciated on unenhanced CT scans but may vary in attenuation depending on the age of the clot (4,12). Small hematomas are crescent shaped but may become biconvex when they are larger and may exert a mass effect on the adjacent renal parenchyma, indenting or flattening the renal margin (1–6,12). When the renal capsule is lacerated, hematoma may enter the perinephric space (12).

Grade II and Grade III Injuries

Grade II injuries include nonexpanding perinephric hematomas confined to the retroperitoneum and superficial cortical lacerations measuring less than 1 cm in depth, whereas grade III injuries are renal lacerations deeper than 1 cm that extend into the medulla. The hallmark of both grade II and grade III lacerations is sparing of the collecting system (1,4).

A perinephric or perirenal hematoma is a poorly marginated, hyperattenuating fluid collection (45–90 HU) that is confined between the renal parenchyma and the Gerota fascia (Fig 4) (1,4,5,12). Other associated findings include

2.

3.

Figures 2, 3. **(2)** Right renal contusion (grade I injury) in a 64-year-old man who was involved in a motor vehicle accident. CT scan shows an ill-defined hypoattenuating area in the renal parenchyma (arrow). **(3)** Acute right subcapsular hematoma (grade I injury) in a 28-year-old man who sustained blunt trauma in a motor vehicle accident. Unenhanced CT scan shows a hyperattenuating hematoma surrounding the right kidney (open arrow), a finding that reflects the presence of fresh blood. A right transverse process fracture (solid arrow) and contrast material within the gallbladder lumen from previous examinations (*) are also noted.

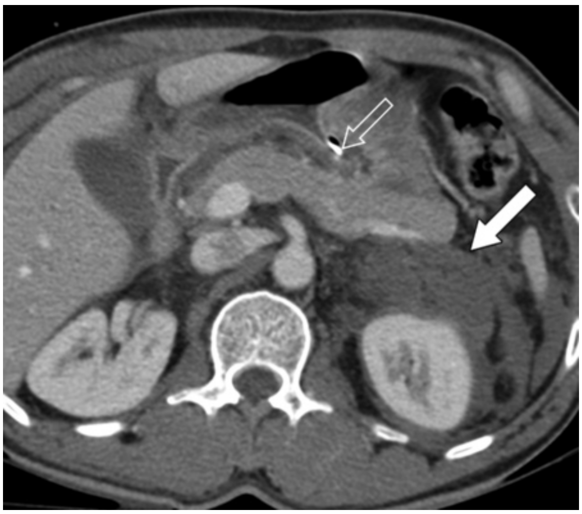
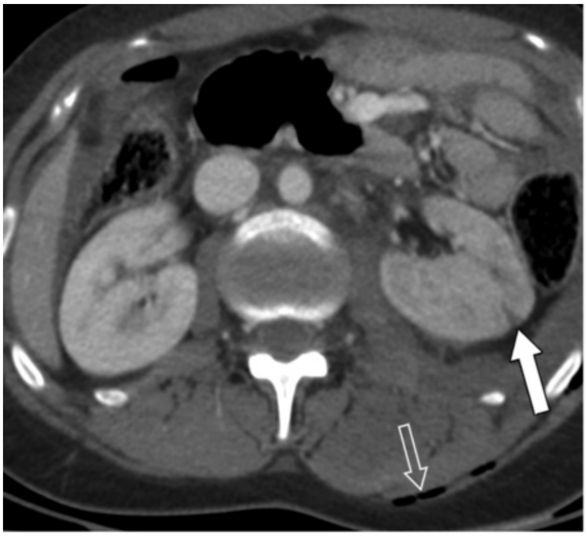


Figure 4. Left perinephric hematoma (grade II injury) in a 60-year-old man who sustained blunt abdominal trauma in a motor vehicle accident. CT scan shows a left perinephric hematoma (solid arrow). A left adrenal hematoma and a deep splenic laceration with perisplenic hematoma and active bleeding were also found. Open arrow indicates a nasogastric tube.

thickening of the lateroconal fascia, compression of the colon, and displacement of the kidney (1). This kind of hematoma may be isolated but is often associated with an underlying renal injury (3) and may cross the midline to the opposite perirenal space along a communicating plane anterior to the lower aorta and the inferior vena cava (1). Despite their size, perinephric or perirenal hematomas usually exert no mass effect on the renal contour, unlike subcapsular hematomas (3).

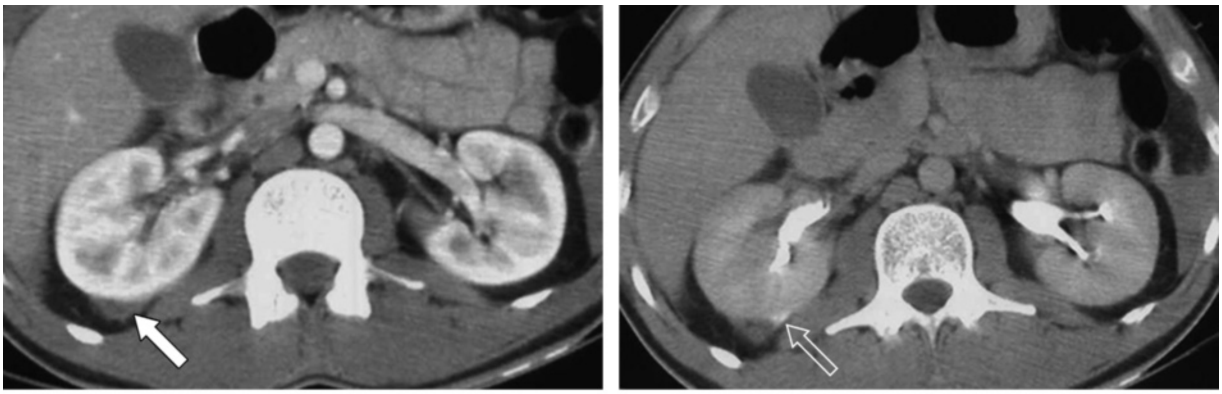
Renal lacerations typically manifest as hypoattenuating, irregular wedge-shaped or linear parenchymal defects or clefts that may fill with blood clots (in which case they appear hyperattenuating) (1,2,5,6,14). Like renal infarctions, lacerations fail to enhance after contrast material administration (1,3,12). They are classified as grade II (Fig 5) or grade III (Fig 6) injuries depending on their depth, but none of them extends into the collecting system, and no urine leakage is found.



5.

6.

Figures 5, 6. **(5)** Left renal laceration (grade II injury) in a 25-year-old woman who was involved in a motor vehicle accident. CT scan shows a left renal laceration (solid arrow). Several rib and transverse process fractures were also found. Note the presence of air in the soft tissues in the posterior abdominal wall (open arrow). **(6)** Renal laceration (grade III injury) in a 32-year-old man who sustained blunt trauma in a motor vehicle accident. Oblique sagittal portal venous phase multiplanar reformatted (MPR) image shows a deep right renal laceration (solid arrow), a perinephric hematoma (*), and hepatic lacerations (open arrows). Delayed CT scans depicted no urine leakage.



a. b.

Figure 7. Right renal laceration extending into the collecting system (grade IV injury) in a 34-year-old man who was involved in a motor vehicle accident. **(a)** Corticomedullary phase CT scan shows a small amount of fluid along the posterior surface of the right kidney (arrow), a finding that was the only clue to the presence of a laceration. **(b)** Delayed excretory phase CT scan shows a subtle area of urinary extravasation (arrow). Follow-up CT performed 1 week later showed spontaneous and complete resolution of the leakage.

Grade IV Injuries

Grade IV injuries include renal lacerations extending through the kidney into the collecting system, injuries involving the main renal artery or vein with contained hemorrhage, and segmental infarctions without associated lacerations.

Lacerations involving the collecting system are characterized by the extravasation of opacified urine into the perirenal space (1–3). In such cases, or whenever significant perinephric fluid

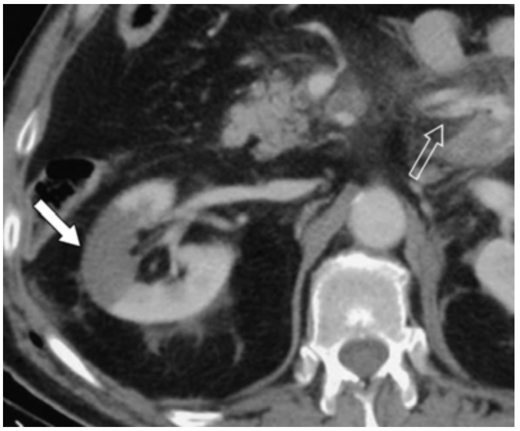


Figure 8. Segmental infarction without associated laceration (grade IV injury) in a 69-year-old man who sustained blunt trauma in a fall from a height of 4 m. Portal venous phase CT scan shows a wedge-shaped segmental infarction of the right kidney (solid arrow) and a left retroperitoneal hematoma with active bleeding that originates from a branch of the splenic artery (open arrow). The bleeding was successfully controlled with angiographic embolization.

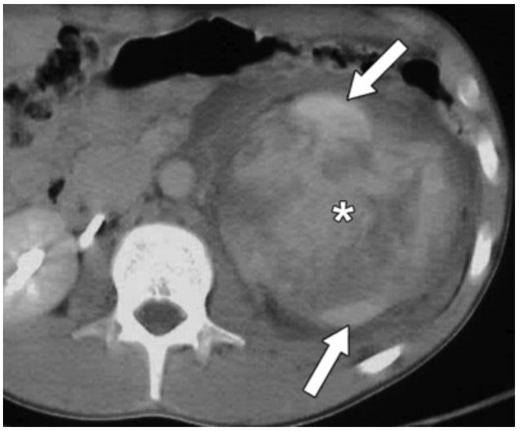


Figure 9. Shattered kidney (grade V injury) in a 16-year-old boy who sustained blunt trauma in a motorbike accident. Delayed excretory phase CT scan shows fracture of the upper and middle portions of the left kidney into multiple fragments (arrows). A fresh, heterogeneous intrarenal hematoma is also observed (*), but no active hemorrhage or urinary leakage was depicted. The patient underwent left nephrectomy.

is seen around the renal hilum on nephrographic phase images, delayed excretory phase images must also be obtained, since opacified urine increases the attenuation of the urine leakage over time (Fig 7) (1,3,12,39).

Segmental infarctions without associated lacerations are caused by thrombosis, dissection, or laceration of an accessory-capsular artery or intrarenal segmental branch (1–5,25,36). They are often multifocal and are usually associated with other renal injuries (3,12). At CT, they manifest as well-demarcated, linear or wedge-shaped nonenhancing areas extending through the renal parenchyma, with the base oriented toward the renal capsule and the apex pointing toward the hilum (Fig 8) (1,3,5,6,11–14,18,40). The relative size of the nephrographic defect correlates directly with the size of the obstructed feeding vessel (40). Immediate or delayed traumatic renal infarction may occur (1,2).

Again, there are some clues that may help radiologists in distinguishing between contusions and segmental infarctions. For example, the latter have better-delineated margins and lack enhancement, whereas the former manifest with more blurred margins and enhance less than the normal adjacent parenchyma.

Grade V Injuries and Active Bleeding

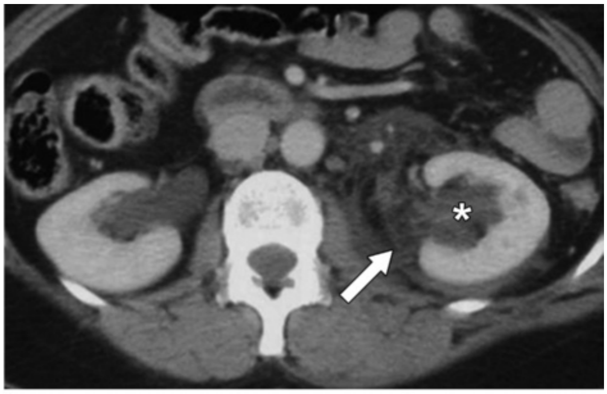
Grade V injuries represent the most severe type of renal trauma and include shattered kidney, partial tears or complete laceration (avulsion) of the ureteropelvic junction, and thrombosis of the main renal artery or vein with devascularization of the kidney (1).

The term *shattered kidney* refers to the most severe form of renal laceration, in which the kidney is fractured into multiple fragments (Fig 9). Shattered kidney is often associated with the presence of one or more devitalized areas, compromise in the excretion of contrast material, injuries to the collecting system, severe hemorrhage, and active arterial bleeding (1–3,6,12). A devitalized segment due to a major laceration may not be appreciated at CT when surrounded by hematoma (2). In some cases, these deep lacerations run parallel to intervascular tissue planes and do not tear any major artery or vein, resulting in a completely amputated upper or lower renal pole that nevertheless maintains an intact blood supply (11).

Ureteropelvic junction injuries occur as a consequence of shearing stress at the renal pelvis (3,4). The ureter is retroperitoneal, and its only

Figures 10, 11. **(10)** Right ureteropelvic junction avulsion (grade V injury) in a 42-year-old woman who was involved in a motor vehicle accident. **(a)** Portal venous phase CT scan shows right hydronephrosis (*) and a small amount of perinephric fluid near the renal hilum (arrow). **(b)** Delayed excretory phase CT scan helps confirm the presence of posteromedial urinary extravasation (arrows). The ureter distal to the point of injury was seen to be unenhanced. **(11)** Partial tear of the left ureteropelvic junction (grade V injury) in a 50-year-old woman who was involved in a motor vehicle accident. **(a)** Portal venous phase CT scan shows left hydronephrosis (*) and a small amount of perinephric fluid (arrow). **(b, c)** Delayed excretory phase CT scans show medial perinephric urinary extravasation (arrow in **b**) and opacification of the distal ureter (arrowhead in **c**).

10a.



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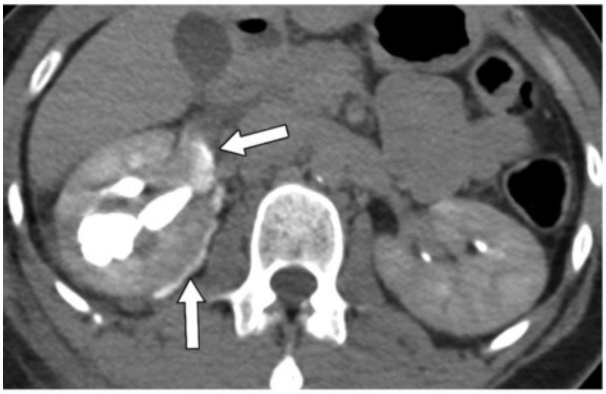

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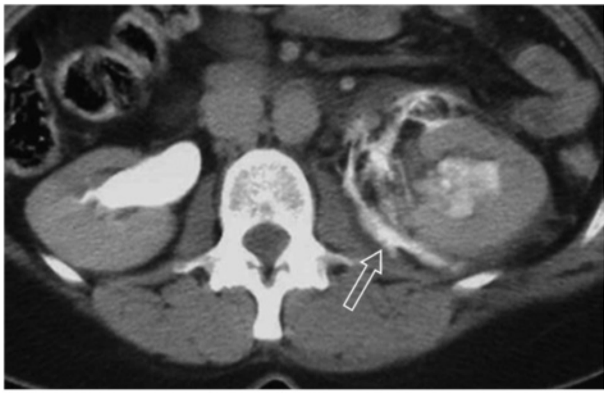

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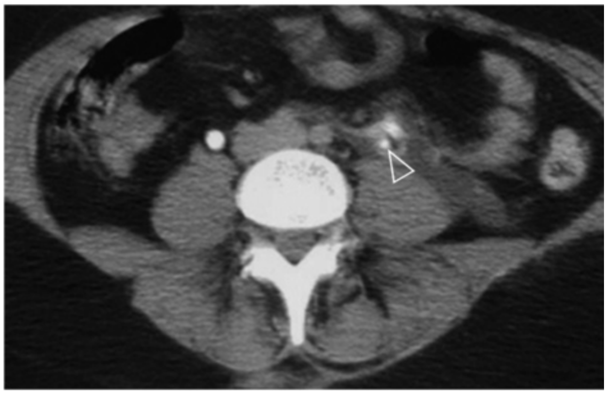
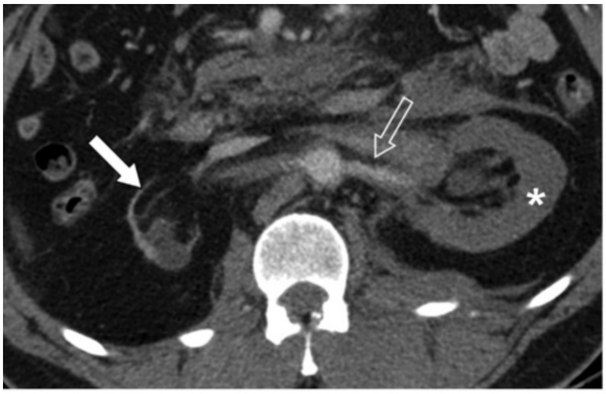


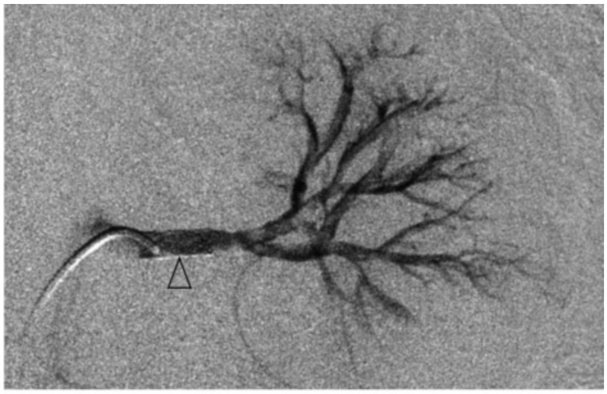
11c.

fixation points are at the ureteropelvic junction and the ureterovesical junction (27,41). With sudden deceleration and the resulting hyperextension, the ureter is tensed across the transverse processes, resulting in laceration or avulsion at its proximal point of fixation (41). Hematuria may be absent in one-third of cases (2,3,27,41). Ureteropelvic junction injuries can be further subdivided into complete avulsions and partial tears, both of which exhibit a characteristic medial or circumferential urinary extravasation (1–4,11,41) with normal renal excretion and an intact caliceal system (2,4,11,18,41). The key to distinguishing partial from complete tears is the presence of contrast opacification in the ipsilateral ureter distal to the point of injury, a finding that is diagnostic for partial tears. If the distal segment of the ureter fails to fill with contrast material, the

Figure 12. Thrombosis of the left main renal artery (grade V injury) in a 48-year-old man with only one kidney who sustained blunt trauma in a fall from a height of 8 m. **(a)** Portal venous phase CT scan shows an atrophic right kidney (solid arrow) and lack of enhancement of the left kidney (*), along with subtle opacification of the left main renal artery (open arrow). The patient underwent arteriography, findings at which confirmed the presence of thrombosis of the left main renal artery. **(b)** Arteriogram shows a stent (arrowhead) that was placed in an attempt to salvage the left kidney. Successful revascularization of the upper two-thirds of the kidney was achieved. **(c)** Follow-up CT scan clearly depicts the stent at the origin of the left renal artery (open arrowhead). However, the parenchyma demonstrates irregular enhancement, with the cortex considerably less enhanced than the medulla, which is also grossly underenhanced. Note also the presence of the "cortical rim" sign (solid arrowhead). These findings were believed to represent acute cortical necrosis secondary to prolonged ischemia. The patient developed renal failure and underwent hemodialysis.



a.



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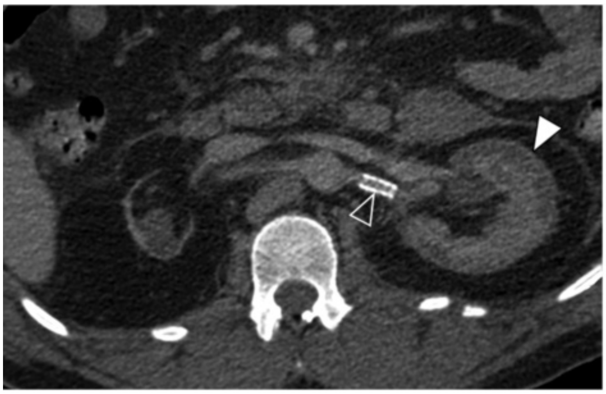
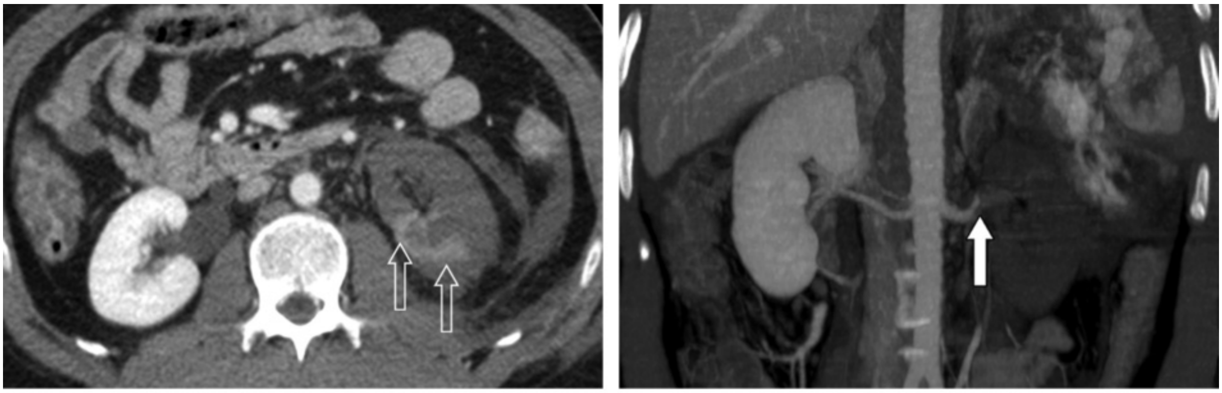


c.

possibility of complete avulsion should be considered (Figs 10, 11) (1–3,6,11,13,18,41,42). The differentiation of ureteropelvic junction avulsion from incomplete tear is crucial (2,3,41), since the former usually requires surgical repair, whereas the latter may be treated conservatively or with stent placement (although a partial tear may be a relative indication for surgical repair if urinary extravasation persists over time).

Renal pedicle injuries account for up to 5% of all renal traumas and are often associated with injuries to other organs. If the injury is isolated, there may be no hematoma or other sign of injury, and hematuria may also be absent (1–3,12). The most common form of vascular pedicle injury is renal artery occlusion (1). The pathogenesis consists of stretching of the renal artery, which produces an intimal tear or dissection, followed by platelet aggregation and subsequent vascular occlusion that progresses distally (1,2,4,43). CT findings include a well-defined subtotal or global absence of parenchymal enhancement with no distortion of the renal contour (1,5,6,12,14,33,40). The abrupt termination of the renal artery at the point of occlusion can be confirmed with angiography (Fig 12) but is sometimes seen on MPR and maximum-intensity-projection images (Fig 13) (33). Retrograde opacification of the left renal vein from the inferior vena cava may also suggest the diagnosis (1,3,5,13). The classic cortical rim sign is produced by thin capsular or subcapsular enhancement due to intact collateral flow through capsular, peripelvic, and periureteric vessels (40,44). However, this sign requires the passage of at least 8 hours to be detected in trauma-induced renal infarction and thus may



a. b.

Figure 13. Thrombosis of the left main renal artery (grade V injury) in a 30-year-old man who sustained blunt trauma in a motor vehicle accident. **(a)** Portal venous phase CT scan reveals a geographic pattern of nephrographic absence in the left kidney. The kidney shows only small areas of faint enhancement in the lower pole (arrows) and is clearly hypoattenuating relative to the normal right renal parenchyma. **(b)** Coronal maximum-intensity-projection image depicts the blind ending of the left main renal artery (arrow).

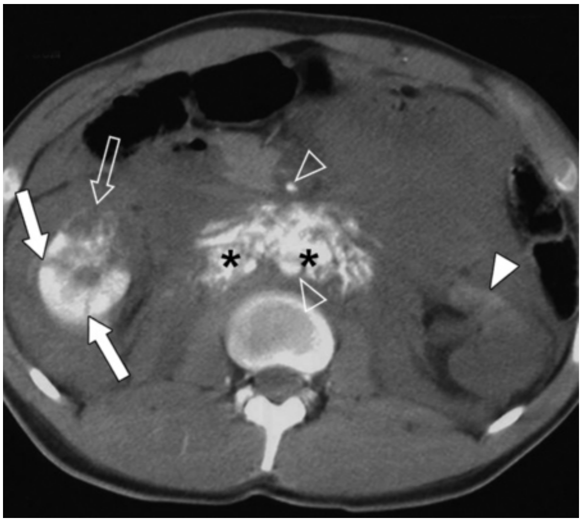
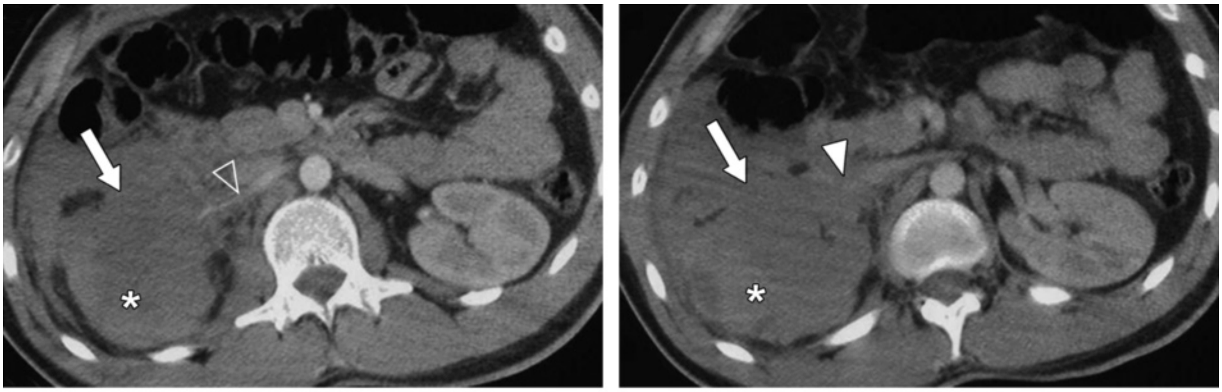


Figure 14. Bilateral vascular pedicle avulsion (grade V injury) in a 19-year-old man with severe blunt trauma from a motorbike accident. Arterial phase CT scan shows a shattered right kidney with multiple lacerations (solid arrows) and a devitalized fragment (open arrow). The left kidney is unenhanced due to vascular damage, except for a slightly enhanced segmental area in the midportion (solid arrowhead). Bilateral perirenal hematoma and signs of severe active bleeding are also seen, with large amounts of fresh blood (*) between the aorta and kidneys. The aorta and superior mesenteric artery (open arrowheads) are narrowed due to hypovolemia. Mediastinal hematoma and hepatosplenic lacerations were also found, with avulsion of the celiac artery, superior mesenteric artery, and right renal vein. The patient underwent splenectomy and left nephrectomy due to complete avulsion of the left renal vascular pedicle, but hemodynamic instability led to his death.

be absent in the acute setting (1–3,12,18,44). Although complete arterial tears involving the tunica muscularis and adventitia occur only infrequently (Fig 14), they produce a massive hematoma between the aorta and the kidney with signs of severe active bleeding (1–4).

Isolated renal vein injuries are the most uncommon type of vascular pedicle injury (1,2). Renal vein thrombosis virtually always occurs in combination with arterial or parenchymal injury (1). Contrast-enhanced CT reveals an enlarged renal vein containing a filling defect (thrombus) and renal changes secondary to acute venous hypertension (interstitial edema), including neph-



a. b.

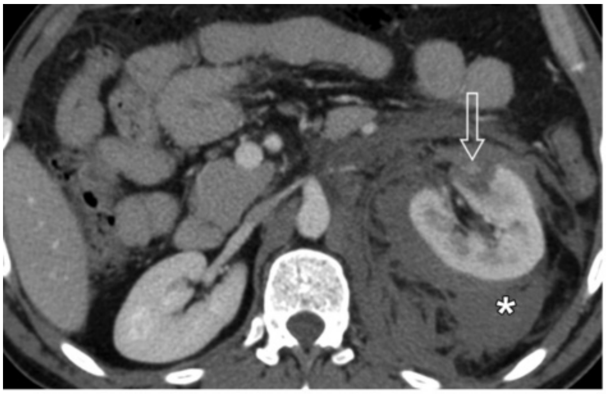
Figure 15. Main renal vein avulsion (grade V injury) in a 23-year-old man who sustained blunt trauma in a motorbike accident. Arterial phase **(a)** and portal venous phase **(b)** CT scans show lack of enhancement of the right kidney (arrow). The proximal segment of the renal artery is opacified but diminished in caliber (arrowhead in **a**), whereas the right main renal vein is not clearly depicted (arrowhead in **b**). A hyperattenuating right perinephric hematoma is also observed (*). Lack of enhancement of the right kidney was believed to be a consequence of both impaired intrarenal arterial flow due to intimal tear or dissection and sudden elevation of interstitial pressure from venous damage. Absence of contrast material excretion was seen on delayed images. A shattered kidney and avulsion of the right main renal vein were found at surgery, and the patient underwent right nephrectomy.

romegaly, a diminished nephrogram with delayed nephrographic progression, and decreased excretion of contrast material into the collecting system (2,3,11–14,40). Lacerations of the renal vein (Fig 15) can be suspected when medial or circumferential subcapsular or perinephric hematoma is found (1,3), although CT may not reliably help detect venous lacerations (2).

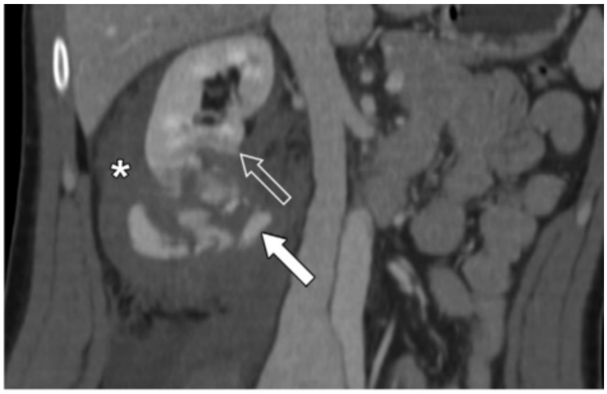
Contrast-enhanced multidetector CT is diagnostic for both pseudoaneurysms and active bleeding in the vast majority of cases, with angiography being performed therapeutically. These findings can be suggested during the early phases of CT when scanning depicts intense enhancement with an attenuation close to that of nearby arteries within a laceration or around an injured kidney (3,6,12,23,45). A pseudoaneurysm is a focal, rounded, well-circumscribed lesion contained within the renal parenchyma or a laceration that enhances during the arterial phase and becomes isoattenuating relative to the blood pool during the delayed phase (1,42). It may persist or enlarge over time and may occasionally cause delayed bleeding or hypertension (3,12). Conversely, active hemorrhage (Figs 16, 17) is rather ill defined, appearing as patchy areas described as linear, flame shaped, or waterfall shaped (1,3,12,23), with high attenuation values ranging from 85 to 370 HU (2). Active hemorrhage is generally associated with fresh hematoma, which often manifests as a fluid-hematocrit level or circumferential layering of lower-attenuation clotted blood (2,3,6,12) that is best appreciated at dynamic contrast-enhanced CT (2). The extravasation point can be used to localize anatomic sites of hemorrhage and to guide angiographic or surgical intervention (45).

The AAST renal injury scale is based on the appearance of the kidney at surgery, and although signs of active bleeding are easily depicted with multidetector CT prior to surgery, they are not explicitly included in any of the vascular lesion categories (grades IV and V). Active hemorrhage can occur even with low-grade injuries and, in

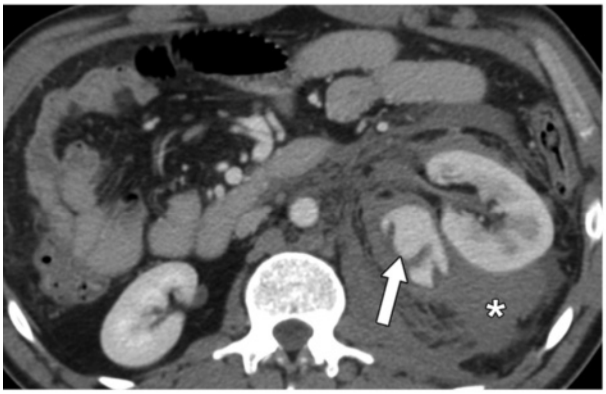
Figures 16, 17. **(16)** Active hemorrhage in a 35-year-old man who sustained left flank penetrating trauma from a stab wound. Portal venous phase CT scans show a deep laceration in the anterior aspect of the left kidney with a blood clot filling the parenchymal gap (arrow in **a**). A left retroperitoneal hematoma is also seen (*). Note the presence of a flame-shaped hyperattenuating focus adjacent to the renal hilum (arrow in **b**), a finding that is consistent with active bleeding. Maximum-intensity-projection images showed no evidence of vascular pedicle injury and no urine leakage. The patient underwent urgent nephrectomy, and the gross surgical specimen showed renal hilum injury with severe active bleeding. **(17)** Active hemorrhage in a 20-year-old man who sustained blunt trauma during soccer practice. **(a)** Oblique coronal portal venous phase MPR image shows a heterogeneous right retroperitoneal hematoma (*) with signs of active hemorrhage (solid arrow). A deep laceration of the lower pole of the kidney is also observed (open arrow). **(b)** Selective renal angiogram shows active bleeding that originates from a segmental branch (arrowhead). Successful embolization was performed with three microcoils. **(c)** Selective renal angiogram shows the microcoils (arrowhead) and no significant loss of parenchymal tissue. The patient underwent nephrectomy owing to a decreasing hematocrit level, pain, and fever.



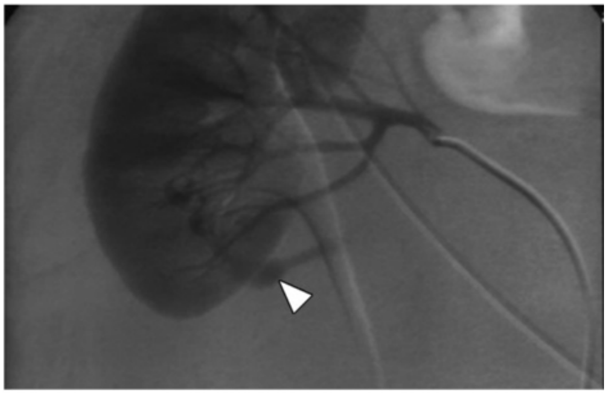
16a.



17a.



16b.



17b.

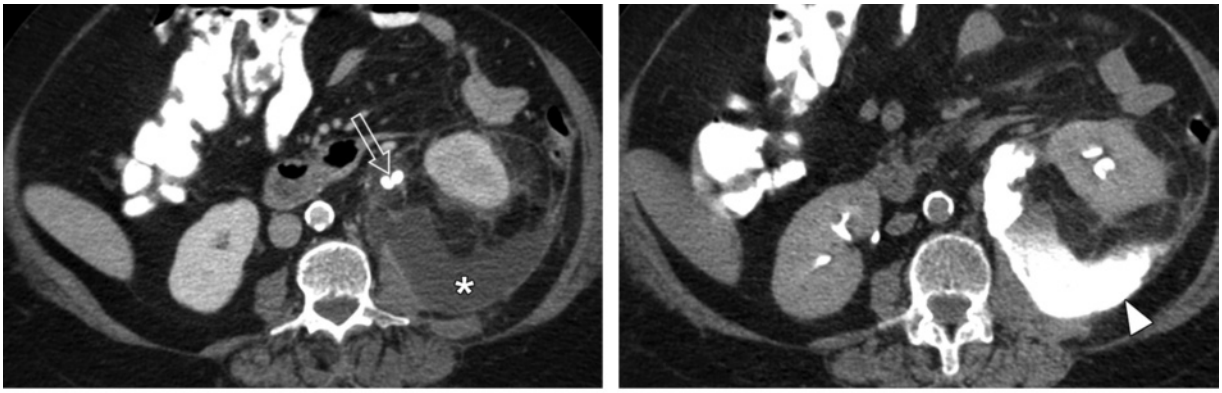
17c.

some cases, due to its life-threatening nature, may induce failure of nonsurgical management or hemodynamic instability that may require arteriography and transcatheter embolization or surgery to prevent exsanguination (3,12,17,45,46).

Traumatic Injuries to Kidneys with Preexisting Abnormalities and Iatrogenic Renal Trauma

Preexisting renal abnormalities predispose the kidneys to an increased risk of injury and a decreased potential for renal salvage following blunt abdominal trauma (1,2,13,42). An underlying renal disorder should be suspected when the severity of the patient's symptoms is disproportionate to the degree of injury suffered (relatively minor or even trivial trauma) (1,2,4,11). Preexisting disease that is first brought to light by trauma is

Figure 18. Urinary extravasation in a 75-year-old woman with known left ureterohydronephrosis who sustained blunt trauma in a fall from a height of 1 m. **(a)** CT scan helps confirm the presence of lithiasis in the proximal left ureter (arrow). A left retroperitoneal fluid collection is also observed (*). **(b)** Delayed phase CT scan shows that the collection has filled with diluted intravenous contrast material (arrowhead).



a. **b.**

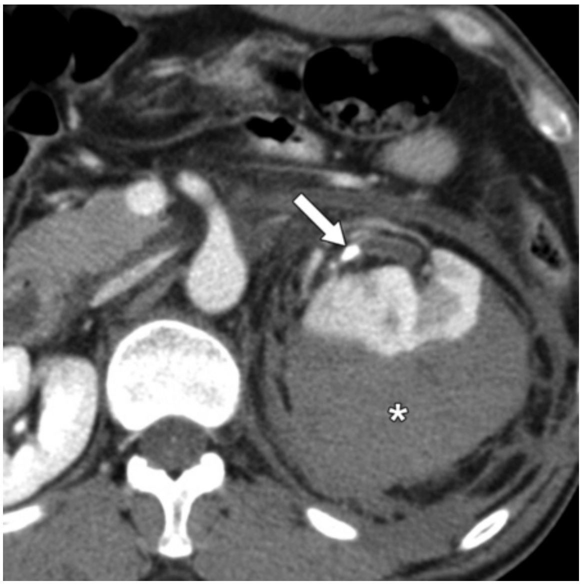


Figure 19. Subcapsular hematoma in a 44-year-old man who presented with abdominal pain and a decreasing hematocrit level after undergoing extracorporeal shock-wave lithotripsy. Portal venous phase CT scan shows a left subcapsular hematoma (*) exerting a mass effect on the underlying renal parenchyma. Note the presence of a renal stone in the ureteropelvic junction (arrow).

more common in children than in adults because of the relatively large renal volume and limited amount of protective perinephric fat and muscle in children (11,13). Preexisting renal cysts are the most common predisposing anomaly and may undergo rupture or bleeding with or without communication with the collecting system (1,2). Other preexisting abnormalities include longstanding hydronephrosis secondary to ureteropelvic junction stenosis or renal stones (Fig 18); extrarenal pelvis; congenital anomalies such as ectopic or horseshoe kidney; rupture of a tumor such as angiomyolipoma or renal cell carcinoma; and transplanted kidney, which is superficial in location and, therefore, more prone to blunt trauma (1,2,4,18,41).

In some cases, renal trauma results as a complication of diagnostic or therapeutic procedures, such as US-guided percutaneous core-needle biopsy, percutaneous nephrostomy, intraabdominal surgery, angiography, or extracorporeal shock-wave lithotripsy (1,5,11). The most frequently reported complications are perirenal hematoma, renal laceration, vascular injuries such as arterial branch laceration or arteriovenous fistula, and pseudoaneurysm formation (Fig 19) (1,5).

Complications of Renal Trauma

Complications occur in 3%–33% of all cases of renal trauma (1,26,42) and can be classified as either early complications or late complications.

Early complications are those that develop within the first month after injury and include urinary extravasation with urinoma formation, infected urinoma, perinephric abscess, sepsis, and delayed bleeding secondary to arteriovenous fistula or pseudoaneurysm (2,18).

Urinary extravasation is the most common complication of renal trauma. It is, by definition, present in all grade IV parenchymal injuries and ureteropelvic junction tears and may also result from forniceal rupture after lesser trauma (Figs 7, 10, 11) (1,5,17,42). Urinomas occur in 1%–7%

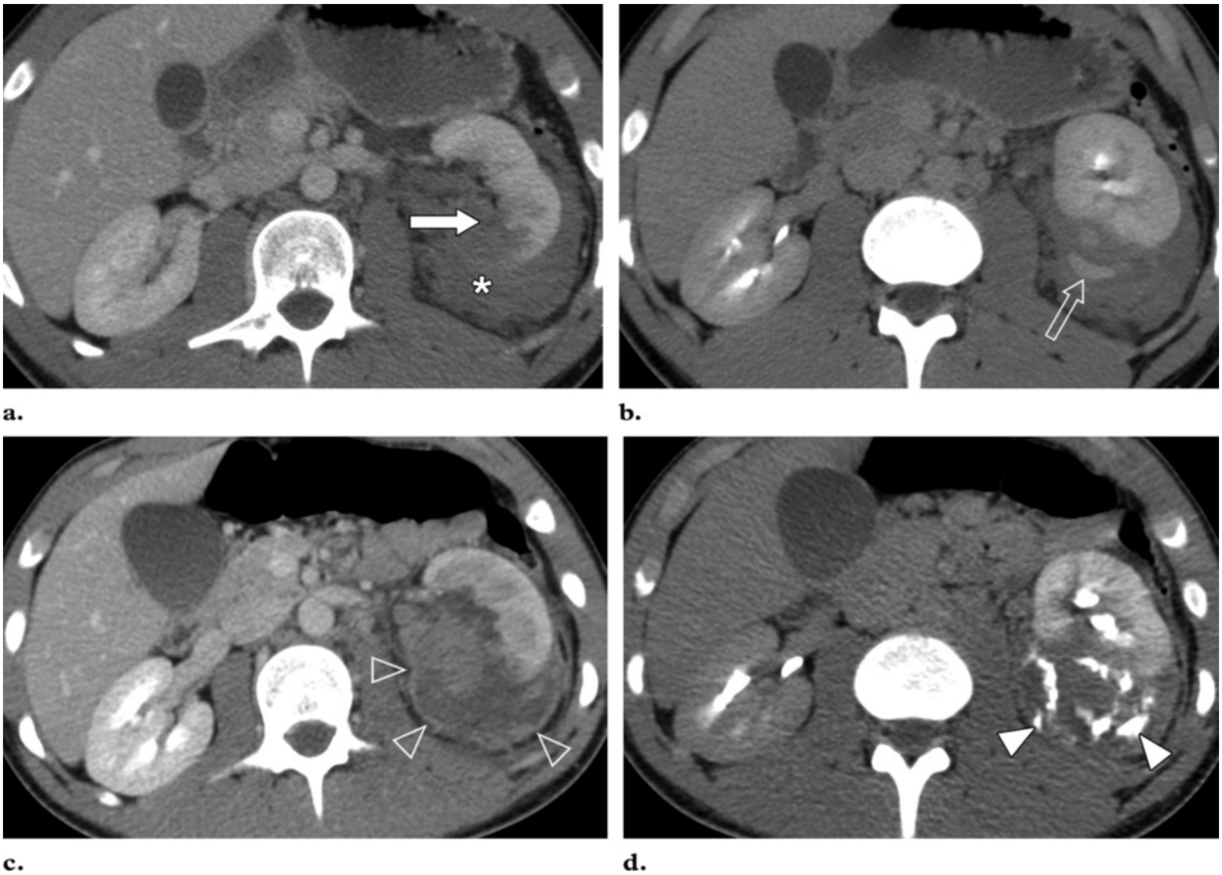


Figure 20. Urinoma in a 17-year-old boy who was involved in a motorbike accident. **(a)** Portal venous phase CT scan shows a deep laceration in the midportion of the left kidney (arrow) and a perirenal hematoma (*). **(b)** Delayed phase CT scan depicts no injury to the excretory system. However, hyperattenuating foci are observed within the hematoma (arrow), a finding that suggests the presence of active bleeding. Findings at arteriography were negative, and the lesion was classified as grade III. **(c)** Follow-up CT scan obtained 14 days later reveals persistence of the perirenal collection, which now manifests with a well-defined capsule (arrowheads). **(d)** Delayed phase CT scan helps confirm that the collection is partially filled with diluted intravenous contrast material (arrowheads).

of cases and consist of a collection of urine that may be encapsulated, although they can also manifest as free fluid. However, most urinomas arise in a subcapsular location or in the perirenal space within the Gerota fascia (39,42). Intraperitoneal urine leaks and urinomas are usually the result of penetrating or iatrogenic injuries (39). As mentioned earlier, delayed phase CT is essential in making the diagnosis, since iodinated urine increases in attenuation over time (Fig 20) (1,39,42).

Urinomas may also be complicated by superinfection or perinephric abscess formation. Infected urinomas and perinephric abscesses can be secondary to either local or systemic bacterial seeding of a urinoma, coexisting enteric or pancreatic injuries, or large areas of soft-tissue loss requiring débridement (2,13,42). Up to 74%–87% of urinary extravasations and small urinomas tend to reabsorb spontaneously (1,2,39). Larger urine leaks and urinomas may require placement of a stent (3) or nephrostomy catheter (3,7,9,12,39,42), whereas persistent or infected collections may benefit from drainage under US or CT guidance (1,13).

Secondary hemorrhage is more frequently seen in deep cortical lacerations, grade V renal trauma, or conservatively managed penetrating trauma. The mean interval between injury and the onset of secondary hemorrhage is approximately 2–3 weeks (1,42). Secondary hemorrhage is often caused by posttraumatic pseudoaneurysm or arteriovenous fistula. The development of either of these entities is less common after blunt abdominal trauma than after penetrating trauma (17,47). When pseudoaneurysm formation occurs, the hemorrhage may initially be contained by the surrounding tissues (vascular adventitia, renal parenchyma, and the Gerota fascia). With progression, however, gross hematuria results from

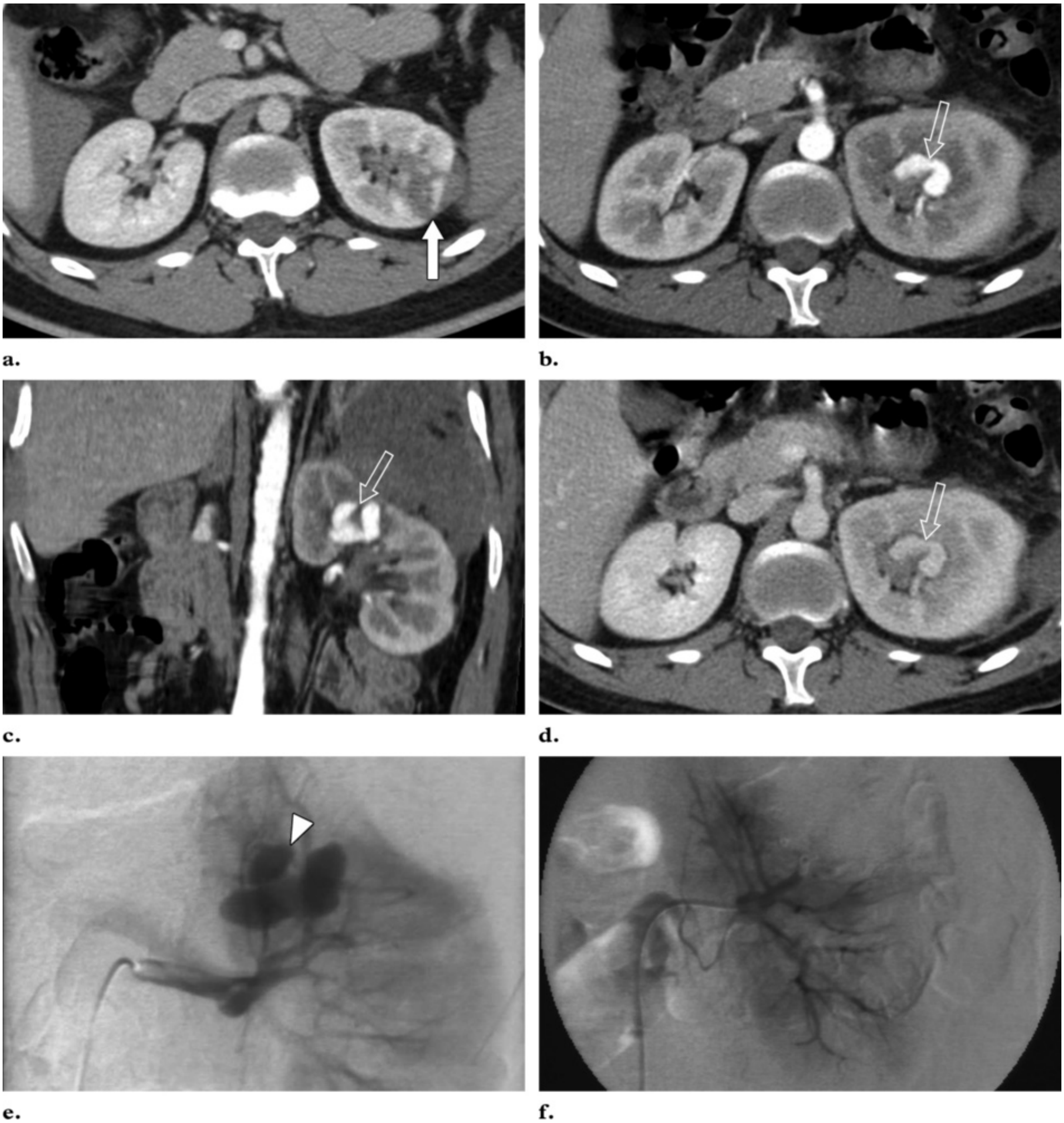


Figure 21. Pseudoaneurysm in a 25-year-old man who sustained penetrating trauma from a stab wound. **(a)** Initial CT scan shows a left renal laceration (arrow). Note the delayed nephrogram of the affected kidney relative to the contralateral kidney. The patient underwent splenectomy due to splenic lacerations, with the renal injury being managed conservatively. The clinical course was obscured by low hematocrit levels, and follow-up CT was performed. **(b, c)** Axial CT scan **(b)** and oblique coronal MPR image **(c)** obtained during the arterial phase show a lobulated masslike lesion (arrow) that is isoattenuating relative to the aorta. **(d)** On a portal venous phase CT scan, the lesion (arrow) is isoattenuating relative to the blood pool. **(e)** Selective arteriogram of the left renal artery depicts the lesion (arrowhead) and shows excellent correlation with the findings on the MPR image (cf **c**), thereby confirming the presence of a pseudoaneurysm that originates from the superior segmental artery. **(f)** Arteriogram obtained after therapeutic embolization shows that the procedure was successful.

communication of the pseudoaneurysm with the collecting system (42,47). A pseudoaneurysm manifests at CT as a round or ovoid lesion that enhances during the arterial phase and becomes isoattenuating relative to the blood pool during the delayed phase (Fig 21) (1,42). Angiography is the standard tool for the diagnosis of pseudoaneurysms and also the first-line treatment (in the form of transcatheter embolization) (1,42,47), although findings from contrast-enhanced multidetector CT are diagnostic for a pseudoaneurysm in the vast majority of cases. Arteriovenous fistula can be suggested at CT if early enhancement of an engorged renal vein and the inferior vena cava is depicted. Small arteriovenous fistulas tend to heal spontaneously, but larger ones do not and may induce compromised renal function, uncontrolled hypertension, or hematuria (1,42). In such cases, superselective embolization is generally a safe and effective treatment modality (42).

Late or delayed complications of renal trauma develop more than 4 weeks after injury and include hypertension, hydronephrosis, calculus formation, and chronic pyelonephritis (2,5,18,42).

Posttraumatic renovascular hypertension may occur anywhere from a few weeks to decades following injury, but on average occurs within 34 months (1,17,42). Several mechanisms have been proposed for its development, including renal artery occlusion, stenosis (Goldblatt kidney), or compression; severe renal contusion; arteriovenous fistula or pseudoaneurysm formation; and chronic contained subcapsular hematoma (2,42). The term *Page kidney* refers to hypertension secondary to constrictive ischemic nephropathy caused by large chronic subcapsular hematomas, which exert a mass effect on the adjacent renal parenchyma, indenting or flattening the renal margin. This condition may lead to diminished renal perfusion, fibrosis, and scarring. At CT, typical findings include a delayed nephrogram of the kidney and a surrounding fibrotic band that may be calcified (1–4). Because spontaneous resolution of posttraumatic hypertension has been reported in many studies, conservative and pharmacologic treatment is strongly advised. Surgery, including renal revascularization, partial nephrectomy, or even total nephrectomy, is the second step in the management of posttraumatic hypertension (42).

Renal Trauma Management

From a practical standpoint, the management of concomitant injuries to the spleen, liver, bowel, or diaphragm often dictates the approach that is ultimately used to treat renal injuries, although nephrectomy or repair of renal injuries will eventually be needed as well (10). The goal of the urologist in a trauma situation is threefold: *(a)* to minimize hemorrhage; *(b)* to maintain urinary flow without obstruction so as to preserve renal function; and *(c)* to prevent extravasation of urine outside the urinary tract, thereby decreasing the risk of local and systemic infection (6,9).

Conservative management is now a widely accepted strategy for all but the most severe renal injuries in stable patients, owing to *(a)* historical evidence that the nephrectomy rate is higher among patients who undergo surgical exploration than among those who simply undergo observation (3,12,18), and *(b)* poor functional renal outcome of surgical repair (3,18,21,26,42). The major benefit of nonsurgical treatment is the avoidance of iatrogenic nephrectomy (8,26). Advances in staging techniques resulting from the increased use of CT, the increasing availability of minimally invasive techniques such as angiographic embolization, and the improvement of intensive care unit facilities have played an important role in this trend toward expectant management (8,9,34), whereas surgical intervention is performed in only 5%–10% of renal injuries and continues to decline in frequency of use (34).

Teaching Point

Nonsurgical management is most commonly used in blunt renal injuries, but conservative protocols have also been applied to penetrating renal injuries (7,17) in patients who present with a low likelihood of secondary complications, surgery, or renal loss (10). Gunshot wounds were traditionally treated surgically because of the higher prevalence of associated injuries, higher risk of contamination by foreign material, and presence of devitalized areas due to blast effect (7,11,18,20,21). Nowadays, however, obligatory surgical exploration is no longer the rule. Proper patient selection made on the basis of hemodynamic stability and accurate staging that excludes intraperitoneal damage may obviate surgery (7,17). Opinion is also divided about whether all renal stab wounds require surgical exploration (11). For example, the need to perform surgery in patients with no associated intraperitoneal injury has been questioned because conservative management that follows the guidelines for blunt trauma cases and antibiotic treatment can be curative, thereby avoiding unnecessary nephrectomies (11,17,18).

Observation is recommended for both grade I and grade II renal lesions (24) because these lesions are self-limiting and tend to heal spontaneously, with normally functioning kidneys and no identifiable morphologic abnormality on subsequent CT scans (2,9,10–18). Most grade III injuries also tend to heal spontaneously, leaving retracted parenchymal scars (12,13).

However, the treatment of patients with major renal injuries (grade IV–V injuries and some grade III injuries) remains controversial (46). Some authors contend that early surgical intervention (reconstructive surgery or nephrectomy) leads to less immediate morbidity, particularly in grade V lesions with associated abdominal injuries that require surgical intervention (16). However, most trauma surgeons and urologists believe in a less aggressive approach if the patient is stable and the clinical situation is appropriate (13,18). Therefore, most patients currently undergo nonsurgical treatment (17,18), with acceptably low morbidity and mortality rates (8,48). Treatment of urinary leaks was discussed earlier, and most segmental infarctions heal spontaneously and produce parenchymal scars, so that conservative management is also the most appropriate approach for these lesions (1–4). Only those infarctions affecting more than 50% of the renal parenchyma or associated with large hematomas, intraperitoneal injuries, or urine leaks may require surgical débridement or repair to prevent the development of urinoma or abscess formation, which may necessitate delayed nephrectomy. Because severe renal injuries are more likely to be associated with injuries to other organs and major trauma typically requires follow-up imaging (14,43), serial CT examinations (48,49) and close and aggressive monitoring of patients with grade IV and grade V injuries are recommended to identify and treat delayed complications by means of direct percutaneous drainage or embolization. This approach has reduced the laparotomy rate in this patient population to approximately 10% (8,12,18,24).

Special mention should be made of the role of routine repeat imaging once nonsurgical management has been selected. Routine repeat imaging of blunt renal injuries 24–48 hours after admission seems appropriate but rarely alters clinical management; thus, a more selective use of CT could offer not only economic benefit but also lower radiation exposure (9,26). Follow-up imaging is unnecessary in the nonsurgical management of grade I–III blunt renal injuries and grade IV renal injuries without urinary extravasation. Proposed indications for follow-up CT include *(a)* grade IV injuries with demonstrated urinary extravasation; *(b)* multiple comorbidities with increased risk for complications from renal trauma; *(c)* severe injuries involving multiple organs; *(d)* clinical signs that may herald progressing complications from blunt renal injury (hemodynamic instability, decreasing hematocrit level, fever); and *(e)* grade V renal injuries that meet the criteria for nonsurgical management. Moreover, many of the delayed complications from blunt renal trauma occur at least 1–3 weeks after injury, so that these complications may still be missed at early repeat imaging. A more cost-effective and efficient screening for delayed complications can be achieved with physical examination, monitoring of vital signs, and simple laboratory tests such as measurement of hematocrit and serum creatinine levels (10,26,17,42).

Vascular damage resulting from renal trauma can be effectively treated with superselective catheter embolization (34). Superselective embolization performed at the time of initial CT or when secondary bleeding occurs in patients undergoing conservative treatment (12,34) can quickly and effectively control bleeding with high precision, minimal procedure-related loss of renal tissue, and low complication rates. However, complications might occur, including renal artery dissection, postembolization syndrome, migration of coils, decrease in renal function, abscess formation, nonexpanding hematoma at the arterial puncture site, and hypertension (13,34,35,42,48,50).

The role of surgery in renal trauma is decreasing in importance. The only absolute indications for surgical exploration are *(a)* life-threatening renal bleeding with associated instability; *(b)* expanding, pulsatile, or uncontained retroperitoneal hematoma (most often due to vascular pedicle avulsion); and *(c)* complete ureteropelvic junction–ureteral avulsion (2,3,7,9,10,12,15,17, 18,34,41,42,46). Relative indications include the presence of any of the following entities: *(a)* large areas of devitalized tissue (more than 50% of the renal parenchyma) with coexisting enteric or pancreatic injuries; *(b)* urinary extravasation that cannot be controlled with conservative strategies; *(c)* incomplete injury staging, most often due to instability from associated injuries; or *(d)* arterial thrombosis (7,8,10,12,15,17,46).

Optimal management of traumatic renal artery injuries has been controversial; options include immediate surgical repair, nephrectomy, and conservative management (43). Traumatic thrombosis of the renal artery must be quickly diagnosed and treated, since permanent and progressive loss of renal function begins after 2–3 hours of renal ischemia (9,12,34). To preserve renal function, surgical repair must be performed within 4 hours of injury, although even then only 14%–29% of kidneys return to normal function (2,7,12,17,43,46,51). For this reason, most urologists will avoid surgery if renal ischemia has exceeded 4 hours and the contralateral kidney is normal (5,9,12,43,52). In such cases, patients require close follow-up to rule out hypertension necessitating delayed nephrectomy (43,51). However, aggressive renal revascularization or vascular stent placement is indicated in the treatment of bilateral renal artery occlusion or unilateral occlusion in a solitary kidney, even if renal ischemia has exceeded 4 hours (2,9,12,43,51,52). Nephrectomy is reserved for cases of active bleeding due to vascular avulsion or severe parenchymal disruption with delayed diagnosis and injury beyond surgical repair, unless there is injury or absence of the contralateral kidney (9). The chances of successful repair are higher in isolated renal vein injury, except when there is avulsion from the inferior vena cava, in which case immediate nephrectomy is usually required (42).

Conclusions

Approximately 10% of all significant blunt abdominal traumatic injuries manifest with renal injury, although it is usually minor. Contrast-enhanced CT is the imaging modality of choice in the evaluation and management of renal trauma, since it provides essential anatomic and functional information. Renal imaging is indicated in cases of *(a)* penetrating trauma and hematuria; *(b)* blunt trauma, shock, and hematuria; and *(c)* gross hematuria. Selective rather than systematic delayed excretory phase imaging should be used to assess the integrity of the excretory system when significant perinephric fluid or deep lacerations are found, so as to rule out urinary leaks. There is a growing trend toward conservative management of renal trauma, except for those cases in which extensive urinary extravasation or devitalized areas of renal parenchyma are found and especially in those cases with associated injuries to other abdominal organs; these cases are particularly prone to complications and usually require surgery.

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Kidney in Danger: CT Findings of Blunt and Penetrating Renal Trauma

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Blunt renal trauma accounts for up to 80%--90% of all cases, with motor vehicle accidents being the most common cause; less common causes include *(a)* a direct blow to the flank or abdomen during an assault, a fight, or a sports activity (eg, bicycling, horseback riding); and *(b)* a fall from a height.

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Although the increased use of CT for the evaluation of blunt trauma has lessened the need for specific indications for renal evaluation, universally accepted indications for renal imaging in blunt trauma include *(a)* gross hematuria; *(b)* microscopic hematuria and hypotension (systolic blood pressure [lt]90 mm Hg) or other associated injuries requiring CT evaluation; and *(c)* blunt trauma with other injuries known to be associated with renal injury (eg, rapid deceleration, fall from a height, direct contusion or hematoma of flank soft tissues, fractures of the lower ribs or thoracolumbar spine), regardless of the presence of hematuria.

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CT has clearly replaced intravenous urography and has become the imaging modality of choice for the evaluation of renal trauma and other associated injuries. CT provides, with short examination times, the essential anatomic and functional information necessary to determine the type and extent of parenchymal, vascular, or collecting system injuries and associated abdominal injuries.

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Nowadays, the most widely accepted and used classification system for renal injuries is the AAST grading system. This system is based on surgical findings (the standard for renal injury staging) and has been validated as a useful tool for the prediction of clinical outcomes in patients with renal trauma. It includes five categories (grades I--V), arranged in order of increasing severity according to depth of injury and involvement of the vasculature or collecting system, and correlates well with any abnormalities detected at CT.

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Advances in staging techniques resulting from the increased use of CT, the increasing availability of minimally invasive techniques such as angiographic embolization, and the improvement of intensive care unit facilities have played an important role in this trend toward expectant management, whereas surgical intervention is performed in only 5%--10% of renal injuries and continues to decline in frequency of use.