Multidetector CT findings of blunt and direct renal trauma with emphasis on politraumatized patients: A pictorial essay.

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Learning objectives

To highlight Multidetector CT (MDCT) imaging findings of blunt and direct renal trauma in politraumatized patients according to the AAST renal injury scale.

To analyze direct and indirect signs of parenchymal, vascular and collecting system injuries.

To describe the mechanisms and clinical features of renal injury, indications for genitourinary imaging, and imaging techniques and protocol.

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.

Background

Urinary tract injuries occur in 3%-10% of all abdominal trauma patients, the kidney being the most commonly injured organ [1-11].

The vast majority (80%-90%) of cases are secondary to blunt abdominal trauma [3,8,12], and most significant renal trauma is associated with injury to other major organs [3,4]. 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 [3,5,10-18].

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 [1-6,13,19,20].

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 [1].
MECHANISM OF RENAL INJURIES

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:

1) **80-90% Blunt abdominal trauma** (sudden deceleration or crush injuries) [1,3,6-9,11,12].
   - Motor vehicle accident (MVA, the most common cause).
   - Direct blow to flank / abdomen during participation in sports (bicycle accidents, horseback riding injuries).
   - Falls from a height.
   - Assaults.

2) **10% Penetrating trauma** (often associated with a nonsterile condition, with increased risk of bacterial growth within the hematoma or urine leakage) [8,11,19,21].
   - Gunshot or stabbing injuries.
   - Iatrogenic injuries (renal biopsies or interventional procedures).

CLINICAL FEATURES OF RENAL TRAUMA

Up to 95% of significant renal injuries present with hematuria [1-4,12]:

- Gross hematuria is generally associated with more severe renal trauma.
- Only 1-5 / 1000 hemodynamically stable patients with microscopic hematuria have significant urinary tract injury (widely accepted that no significant urinary tract injury occurs in the absence of gross hematuria and shock in an adult patient) [1,4,7,11,14,19,20].
- May be absent in 10-25% of cases [1,4,7,1,12,19], specially when ureteral, vascular pedicle injuries or ureteropelvic junction (UPJ) avulsion occurs. In such cases, there is no direct relationship between the degree of hematuria and the extent of renal injury.

INDICATIONS FOR GENITOURINARY IMAGING

1) **Blunt trauma:** The increased use of CT has lessened the need for specific indications for renal evaluation [18]. Universally accepted indications include [1-4,6,7,11-14,19,20-27]:

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• Gross hematuria.
• Microscopic hematuria and hypotension (systolic pressure <90 mm Hg) or other associated injuries requiring CT evaluation.
• Blunt trauma with other injuries known to be associated with renal injury (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.

2) Penetrating injury: 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. Remember that absence of hematuria does not rule out the possibility of renal injury.

IMAGING TECHNIQUES

Focused Assessment with Sonography for Trauma (FAST) [1,3,19,28-33].

• Primary goal: Identification of free fluid (= hemoperitoneum) in the unstable patient. If positive, exploratory laparotomy is mandatory (solid organ injury is found in 80-90% of cases)
• Main disadvantages: a) Cannot reliably help differentiate blood extravasated urine or other body fluids, b) Low sensitivity for the detection of retroperitoneal blood or injury, injury to solid organs or hollow viscera, and c) 65% of isolated renal injuries may have no associated peritoneal fluid.

Angiography

• Diagnosis: Less frequently used for the diagnosis of suspicious renal artery injuries, as MDCT is capable of accurately demonstrate vascular pedicle injuries and extravasation of intravenous contrast material [1-4,9,20,34].
• Therapeutic implications [1,4,9,11,19,20,35,36]: As conservative, nonsurgical management of trauma patients is now widely accepted, angiography with transcatheter embolization is increasingly being used as the modality of choice for treatment of active arterial bleeding, pseudoaneurysm or arteriovenous fistula. Other generally accepted indications are the evaluation of late complications such as hypertension and preoperative "mapping"[3,12].

Computed Tomography

CT has become the imaging modality of choice for the evaluation of renal trauma and other associated injuries, providing the essential anatomic and functional information necessary to determine the type and extent of parenchymal, vascular, or collecting system injuries and associated abdominal injuries [1-4,7,11,13,14,19,20,28]. 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 [14].

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 [12]. Whenever urinary tract injury is clinically suggested, it is necessary to perform a specially designed CT examination [6].

- Initial nonenhanced study: helpful in detecting acute bleeding or intraparenchymal hematoma that may become isoattenuating relative to the normal renal parenchyma at postcontrast CT [26,37,38].

- Intravenous contrast material should be administered to all patients, on order to detect not only solid organ but also physiologic variants and vascular injuries [1-,12,13,19,24,37]. Then, abdominal and pelvic MDCT images are obtained.

Usually, a portal venous phase is obtained [1,3,13,14,38], but whenever vascular examination is necessary, a bolus-tracking multiphase CT can be performed during the arterial and nephrographic phases.

A selective use of 5-minute delayed CT of the abdomen and pelvis is recommended 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 [1-4,5,13-15,24,26,28,39,40]. It is also useful in distinguishing between active bleeding and pseudoaneurysm [39].

**SPECTRUM OF CT FINDINGS**

Nowadays, the most widely accepted and used classification system for renal injuries is the AAST grading system [1,3,19], which is based on surgical findings (the standard for renal injury staging) [20] and has been validated as a useful tool for the prediction of clinical outcomes in patients with renal trauma [9-11,27]. 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) on page 13 [1,2].

**GRADE I INJURIES**
Grade I injuries are the most common type of renal injury (75%-85%) [1-7,15,20].

**Contusions**

Visualized as poorly marginated round or ovoid areas of decreased enhancement (Fig. 2) on page 14 and a delayed or persistent nephrogram compared with normal adjacent regions [1-7,13,15,20]. 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 [1,2].

Differential diagnosis with segmental infarctions (infarctions are wedge-shaped and do not enhance, while contusions do [1-4,12,13].

**Nonexpanding subcapsular hematomas without parenchymal laceration.**

Less frequently seen in blunt trauma than perinephric hematomas [4].

Acute stage: Eccentric, unenhanced, hyperattenuating fluid collection that is confined between the renal parenchyma and the renal capsule (best appreciated on unenhanced CT scans) (Fig. 3) on page 15[4-7].

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 [1-7,13]. When the renal capsule is lacerated, hematoma may enter the perinephric space [13].

**GRADE II AND GRADE III INJURIES**

**Grade II: Perinephric hematoma confined to the retroperitoneum:** Poorly marginated, hyperattenuating fluid collection (45-90 HU) confined between the renal parenchyma and the Gerota fascia (Fig.4) on page 16 [1,5,6,13]. Other associated findings include thickening of the lateroconal fascia, compression of the colon, and displacement of the kidney [1,2].

They may be isolated or associated with an underlying renal injury [4], and may cross the midline to the opposite perirenal space along a communicating plane anterior to the lower aorta and the inferior vena cava [1,2]. Usually, no mass effect on the renal contour is observed [4]
Renal lacerations (grade II and III): Hypoattenuating, irregular wedge-shaped or linear parenchymal defects or clefts that may fill with hyperattenuating blood clots [1,2,6,7,15] and fail to enhance after contrast material administration [1,2,4,13]. They are classified as grade II when the laceration measures less than 1 cm in depth (Fig. 5) on page 17 or grade III when they are deeper than 1 cm and extend into the medulla (Fig. 6). None of them extends into the collecting system, and no urine leakage is found [1,5].

GRADE IV INJURIES

Lacerations involving the collecting system

They are characterized by the extravasation of opacified urine into the perirenal space [1-4]. In such cases, or whenever significant perinephric fluid 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) on page 19 [1,2,4,13,40].

Segmental infarctions without associated laceration

Caused by thrombosis, dissection, or laceration of an accessory-capsular artery or intrarenal segmental branch [1-6,26,37]. Often multifocal and associated with other renal injuries [4,13].

CT: 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) on page 20 [1,4,6,7,12-15,19,41]. The relative size of the nephrographic defect correlates directly with the size of the obstructed feeding vessel [41]. Immediate or delayed traumatic renal infarction may occur [1,2,3].

It usually resolves spontaneously in the form of parenchymal scars.

GRADE V INJURIES AND ACTIVE BLEEDING

Shattered kidney

It represents the most severe form of renal laceration. The kidney is fractured into multiple fragments (Fig. 9), on page 20 and 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 [1-4,7,13].
Ureteropelvic junction injuries

Due to shearing stress at the renal pelvis [4,5]. During rapid deceleration or hyperextension the kidney pulls on the relatively fixed ureter and vascular pedicle [42].

Hematuria may be absent in one-third of cases [3,4,28,42].

Can be further subdivided into complete avulsions and partial tears, both of which exhibit a characteristic medial or circumferential urinary extravasation [1-5,12,42] with normal renal excretion and an intact caliceal system [3,5,12,19,42].

Key to distinguishing partial (Fig. 10) on page 21 from complete (Fig. 11) on page 22 tears: The presence of contrast opacification in the ipsilateral ureter distal to the point of injury is diagnostic for partial tears [1-4,5,12,14,19,42,43]. Complete tears require surgical repair while partial tears may be treated conservatively or with stent placement [3,4,42].

Renal pedicle injuries

5% of all renal traumas, often associated with injuries to other organs. If isolated, there may be no hematoma or other sign of injury, and hematuria may also be absent [1-4,13].

Renal artery occlusion: Most common form of vascular pedicle injury [1,2]. It is due to stretching of the renal artery, which produces intimal tear or dissection, followed by platelet aggregation and subsequent vascular occlusion that progresses distally [1-3,5,44].

CT findings [1,2,4,6,7,13-15,32,41]:

- Well defined subtotal or global absence of parenchymal enhancement
- No distortion of the renal contour
- Abrupt termination of the renal artery at the point of occlusion can be confirmed with angiography (Fig. 12) on page 23 but is sometimes seen on MPR and maximum-intensity-projection images (Fig. 13) on page 23 [34].
- Retrograde opacification of the left renal vein from the inferior vena cava
- "Cortical rim sign": thin capsular or subcapsular enhancement due to intact collateral flow through capsular, peripelvic, and periureteric vessels. This sign requires the passage of at least 8 hours to be detected in trauma-induced renal infarction and thus may be absent in the acute setting [1-4,13,19,42,45,46].
Complete arterial tears involving the tunica muscularis and adventitia occur only infrequently (Fig. 14 on page 24). They produce a massive hematoma between the aorta and the kidney with signs of severe active bleeding [1-5].

**Isolated renal vein injuries**

Isolated renal vein injuries are the most infrequent type of renal vascular pedicle injury [1-3].

*Renal vein thrombosis* virtually always occurs in combination with an arterial or parenchymal injury [1, 2].

CT findings [3,4,12-15,41]:

- Enlarged renal vein containing a filling defect (thrombus)
- Renal changes secondary to acute venous hypertension (interstitial edema): nephromegaly, diminished nephrogram with delayed nephrographic progression, and decreased excretion of contrast material into the collecting system

*Laceration of the renal vein* (Fig. 15) on page 25 manifests at CT as a medial or circumferential subcapsular or perinephric hematoma [1, 2, 4], although CT may not reliably help detect venous lacerations [3].

**Pseudoaneurysms and active bleeding**

Contrast-enhanced MDCT is diagnostic for both in the vast majority of cases, with angiography being performed therapeutically.

CT findings: Intense enhancement with an attenuation close to that of nearby arteries within a laceration or around an injured kidney during the early phases of CT [4,5,13,24,46].

- Pseudoaneurysm: Focal, rounded, well-circumscribed lesion that enhances during the arterial phase and becomes isoattenuating relative to the blood pool during the delayed phase [1,43].
- Active hemorrhage (Figs. 16 on page 27, 17 on page 27): Ill defined, described as linear, flame-shaped, or waterfall shaped [1,2,4,13,24]. Generally associated with fresh hematoma, which often manifests as a fluid-hematocrit level or circumferential layering of lower-attenuation clotted blood [3,4,7,13].
Although signs of active bleeding are easily depicted with MDCT prior to surgery, they are not explicitly included in any of the vascular lesion categories of the AAST grading system (grades IV and V) [1]. Active hemorrhage can occur even with low-grade injuries and, in 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 [1,4,13,18,46,47].

**TRAUMATIC INJURIES TO KIDNEYS WITH PREEXISTING ABNORMALITIES AND IATROGENIC RENAL TRAUM**

**Preexisting renal abnormalities** predispose the kidneys to an increased risk of injury and a decreased potential for renal salvage following blunt abdominal trauma [1-3,14,43].

Preexisting disease that is first brought to light by trauma is more common in children than in adults.

Preexisting renal cysts are the most common predisposing anomaly and may undergo rupture or bleeding with or without communication with the collecting system [1-3]. Other preexisting abnormalities include longstanding hydronephrosis secondary to ureteropelvic junction stenosis or renal stones (Fig. 18); on page 28extrarenal 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 [1-4,19,42].

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 shockwave lithotripsy [1,2,6,12]. 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) on page 29[1,6].

**COMPLICATIONS OF RENAL TRAUMA**

Complications occur in 3%-33% of all cases of renal trauma [1,27,43] and can be classified as either early complications or late complications.

**Early complications (those that develop within the first month after injury)** [3,19].
• **Urinary extravasation and urinoma formation:**
  • Urinary extravasation is the most common complication. It is present in all grade IV parenchymal injuries and ureteropelvic junction tears and may also result from fornical rupture (Figs. 7 on page 19, 10 on page 21, 11 on page 22) [1,6,18,43].
  • Urinoma formation (1%-7%): Collection of extravasated urine, typically in a subcapsular location or in the perirenal space within the Gerota fascia (Fig. 20) on page 29 [40,41]. Urinomas may also be complicated by superinfection or perinephric abscess formation. Delayed phase CT is essential in making the diagnosis [1,2,40,43].
  • Up to 74%-87% of urinary extravasations and small urinomas tend to reabsorb spontaneously [1-3,40]. Larger urine leaks and urinomas may require placement of a stent or nephrostomy catheter [4,8,10,13,40,43], whereas persistent or infected collections may benefit from drainage under US or CT guidance [1,2,14].

• **Secondary hemorrhage**
  • More frequently seen in penetrating trauma, deep cortical lacerations, grade V renal trauma and conservatively managed penetrating trauma [18,48].
  • Mean time interval approximately 2-3 weeks [1,2,43]
  • Often caused by [1,2,43]
    • Post-traumatic pseudoaneurysm: round or ovoid lesion that enhances during the arterial phase and becomes isoattenuating relative to the blood pool during the delayed phase (Fig. 21 on page 30)
    • Arteriovenous fistula (AVF): early enhancement of an engorged renal vein and the inferior vena cava.
      • Small ones tend to heal spontaneously. Large ones do not, and may induce compromised renal function, uncontrolled hypertension, or hematuria.

**Late or delayed complications (developing more than 4 weeks after injury)** [3,6,19,43]

• **Hydronephrosis**
• **Calculi formation**
• **Chronic pyelonephritis**
• **Posttraumatic renovascular hypertension:** may occur anywhere from a few weeks to decades following injury, but on average occurs within 34 months [2,18,43].
  • Mechanisms: Renal artery occlusion, compression or stenosis (Goldblatt kidney); severe renal contusion; arteriovenous fistula or pseudoaneurysm formation [3,43].
  • Page kidney: 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. At CT, typical findings include a delayed nephrogram of the kidney and a surrounding fibrotic band that may be calcified [1-5].

- Because spontaneous resolution has been reported in many studies, conservative and pharmacologic treatment is strongly advised.

**RENAL TRAUMA MANAGEMENT**

**Conservative management** is now a widely accepted strategy for all but the most severe renal injuries in stable patients, owing to historical evidence that the nephrectomy rate is higher among patients who undergo surgical exploration than among those who simply undergo observation [4,13,19], and poor functional renal outcome of surgical repair [4,19,22,27,43].

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].

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].

- Observation is recommended for both grade I and grade II and most grade III renal lesions [13, 14, 25] because these lesions are self-limiting and tend to heal spontaneously, with normally functioning kidneys [3,10,11-19].
- Treatment of patients with major renal injuries (grade IV-V injuries and some grade III injuries) remains controversial: surgical intervention versus less aggressive approach. Because severe renal injuries are more likely to be associated with injuries to other organs and major trauma typically requires follow-up imaging [15,44], serial CT examinations [49,50] 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% [9,13,19,25].
- Vascular damage can be effectively treated with superselective catheter embolization [34] performed at the time of initial CT or when secondary bleeding occurs in patients undergoing conservative treatment [13,35]. It can quickly and effectively control bleeding with high precision, minimal procedure-related loss of renal tissue, and low complication rates [14,35,36,43,49,51].

The role of surgery in renal trauma is decreasing in importance.
• **Absolute indications**: [3, 4, 8, 10, 11, 13, 16, 18, 19, 35, 42, 43, 47].
  - Life-threatening renal bleeding with associated instability
  - Expanding, pulsatile, or uncontained retroperitoneal hematoma (most often due to vascular pedicle avulsion)
  - Complete ureteropelvic junction-ureteral avulsion.

• **Relative indications**: [8, 9, 11, 13, 16, 18, 47]
  - Extensive devitalized tissue (>50% of renal parenchyma) with coexisting enteric or pancreatic injuries
  - Urinary extravasation that cannot be controlled with conservative strategies
  - Incomplete injury staging, most often due to instability from associated injuries
  - Arterial thrombosis.
    - Angiography is required to confirm the diagnosis in most cases.
    - If renal ischemia > 4 hours and the contralateral kidney is normal à most urologists avoid surgery (only 14 -29 % of unilateral cases return to normal renal function) [3, 6, 8, 10, 13, 18, 44, 47, 52, 53].
    - Revascularization should be attempted in patients with solitary kidney or bilateral thrombosis even if ischemia time > 4 hours. [3, 10, 13, 44, 52, 53]

**Images for this section:**
## AAST Renal Injury Scale

<table>
<thead>
<tr>
<th>GRADE</th>
<th>TYPE OF INJURIES</th>
<th>DESCRIPTION OF INJURY</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Normal</td>
<td>Hematuria with normal imaging studies.</td>
</tr>
<tr>
<td></td>
<td>Contusion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hematoma</td>
<td>Nonexpanding subcapsular hematomas (with no laceration).</td>
</tr>
<tr>
<td>II</td>
<td>Hematoma</td>
<td>Nonexpanding perinephric hematomas confined to the retroperitoneum.</td>
</tr>
<tr>
<td></td>
<td>Laceration</td>
<td>Superficial cortical lacerations less than 1 cm in depth without collecting system injury (no extravasation).</td>
</tr>
<tr>
<td>III</td>
<td>Laceration</td>
<td>Renal lacerations greater than 1 cm in depth without collecting system injury (no extravasation).</td>
</tr>
<tr>
<td></td>
<td>Laceration</td>
<td>Renal lacerations extending through the kidney into the collecting system.</td>
</tr>
<tr>
<td>IV</td>
<td>Vascular</td>
<td>Injuries involving the main renal artery or vein with contained hemorrhage. Segmental infarctions without associated lacerations.</td>
</tr>
<tr>
<td></td>
<td>Laceration</td>
<td>Shattered or devascularized kidney. Urteropelvic junction (UPJ) avulsions.</td>
</tr>
<tr>
<td>V</td>
<td>Vascular</td>
<td>Complete laceration (avulsion) or thrombus of the main renal artery or vein which devascularizes the kidney.</td>
</tr>
</tbody>
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**Fig. 1:** AAST renal injury scale
Fig. 2: Renal contusions present as poorly marginated round or ovoid areas (open arrow) of decreased enhancement in the renal parenchyma
Fig. 3: Acute right subcapsular hematoma (grade I injury). Unenhanced CT scan shows a hyperattenuating hematoma surrounding the right kidney (open arrow). A right transverse process fracture (solid arrow) and contrast material within the gallbladder lumen from previous examinations (*) are also noted.
Fig. 4: Left perinephric hematoma (grade II injury) in a 60-year-old man who sustained blunt abdominal trauma in a motor vehicle accident (MVA). 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.
Fig. 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).
**Fig. 6:** Grade III renal laceration in a 39-yo male who sustained crush injuries. Bilateral renal lacerations, multiple rib fractures and splenic lacerations were found. Note the presence of a deep renal laceration in the right kidney (solid arrowhead in a). No excretory system leakage was demonstrated on the delayed excretory phase (coronal image b).

**Fig. 7:** Grade IV injury. Right renal laceration involving the collecting system. A small amount of perirenal fluid along the posterior surface of the right kidney is observed (solid arrow in a). This finding was the only clue to this small laceration. Delayed image b shows
a tiny area of urinary contrast extravasation (open arrow). Follow-up CT scan (images c and d) shows spontaneous and complete resolution 1 week later.

**Fig. 8:** Grade IV renal injury. 69-yo male who sustained blunt trauma secondary to a fall from a height of 4 meters. A segmental infaction of the right kidney is depicted as a wedge shaped area of decreased attenuation (solid arrow in a). A left retroperitoneal hematoma posterior to the pancreas with active vascular contrast extravasation is also observed (open arrow in a). Active bleeding from a splenic arterial branch was demonstrated at arteriography, therefore embolization was performed (open arrowheads in b). Faint intimal irregularities suggesting dissection in the proximal right main artery were also observed (circle in b).
Fig. 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.
Fig. 10: Grade V injury. Left UPJ partial tear in a 50-yo female involved in a MVA. A small amount of posteromedial perinephric and periureteral fluid (solid arrow in a and open arrow in b) is observed. Matched delayed excretory phase images c and d show medial perinephric urinary contrast extravasation and opacification of the distal ureter (red circle in d).

Fig. 11: Grade V injury. Right UPJ avulsion in a 42 yo-female involved in a MVA. Right hydronephrosis and a tiny amount of perinephric fluid near the renal hilium are depicted (open arrow in a). On delayed excretory phase images, a posteromedial urine leakage is
demonstrated (solid arrows in b), with absence of enhancement of the distal ureter (solid arrowhead in coronal image c).

**Fig. 12**: Grade V renal injury. Complete occlusion of the main right renal artery in a 54-yo female secondary to a fall from a height. Absence of renal enhancement is depicted (red circle in a), but the renal vein remains opacified (open arrow in a). This finding was confirmed at arteriography (solid arrow in b). The patient was managed with conservative treatment. Follow up CT performed 1 month later shows atrophic changes and severe delayed enhancement in the portal venous phase (green circle in c).

**Fig. 13**: Grade V renal injury. Thrombosis of the main left renal artery which devascularizes the kidney in a 30-yo male who sustained blunt trauma in a MVA. Small
segmental areas of normal attenuation values are observed in the lower pole of the kidney (open arrows in a). Coronal MIP reconstruction depicts a lack of opacification of the left renal artery (solid arrow in b), suggesting the presence of intimal tear or thrombosis.

**Fig. 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.
**Fig. 15:** Renal vein avulsion. Grade V renal injury. 23 yo-male who sustained blunt trauma in a motorbike accident. The right kidney presents lack of enhancement (red circle in a) and absence of contrast material excretion (blue circle in c). The proximal segment of the renal artery is opacified (open arrow in a), but the main right renal vein is not clearly depicted (solid arrow in b). A large hyperdense right perinephric hematoma is observed (*). At surgery, a shattered kidney and avulsion of renal vein was found. The patient underwent nephrectomy.

**Fig. 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 flameshaped 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 urine leakage. The patient underwent urgent nephrectomy, and the gross surgical specimen showed renal hilum injury with severe active bleeding.
Fig. 17: 20-yo stable male who sustained blunt trauma during sport (football) practice. A heterogeneous right retroperitoneal hematoma (*) in a and b) with active hemorrhage signs is depicted (solid arrows in a, b and c). A lower pole complete laceration of the right kidney (open arrow in c) with intact excretory system is observed. Selective renal angiogram shows bleeding depending on a segmental branch (blue circle in d). Successful embolization with 3 microcoils was performed (red circle in d and e), with no significant loss of parenchymal tissue but the area of laceration. CT scan obtained 5 days later (f) depicts no contrast material extravasation. The patient finally underwent nephrectomy owing to a decreasing hematocrit level and increasing pain and fever.

Fig. 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).

**Fig. 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).
Fig. 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).
Fig. 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.
Conclusion

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.

Personal Information

Raquel Cano Alonso studied at the Universidad Complutense de Madrid, where she graduated in Medicine in 2004, and completed her residency in radiology at Hospital Universitario Doce de Octubre (Madrid, Spain) in 2009.

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References


