Signature: © Pol J Radiol, 2013; 78(4): 27-35
DOI: 10.12659/PJR.889780

Polish Journal of Radiology
www.PolRadiol.com
REVIEW ARTICLE

Received: 2013.09.13
Accepted: 2013.10.09

Renal trauma imaging: Diagnosis and management. A pictorial review

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Summary

Background: The purpose of this review is to illustrate and discuss the spectrum of imaging findings, particularly computed tomography (CT), of blunt and penetrating renal trauma, based on our own materials, according to the American Association for Surgery of Trauma (AAST) renal injury grading scale. The article also indicates the conditions in which interventional radiology procedures can be applied for the management of renal trauma.

Material/Method: Cases for this pictorial review were selected from the imaging material collected at the Radiology Department of Hamad Medical Corporation during a 14-year period from 1999 to 2012. The material includes 176 cases (164 males and 12 females) with confirmed blunt or penetrating renal trauma. Following abdominal trauma, all patients had a CT examination performed on admission to the hospital and/or during hospitalization. The most representative and illustrative cases of renal trauma were reviewed according to CT findings and were categorized according to the AAST grading system.

Discusion: The review describes a spectrum of imaging presentations with special emphasis on the 5 grades of renal injury on a CT according to the AAST scale.

The most representative cases were illustrated and discussed with indications of possible interventional radiology treatment. Two groups of patients not included in the AAST grading system were presented separately: those with preexisting renal abnormalities and those with sustained iatrogenic renal injury.

Conclusions: Proper application of renal trauma grading scale is essential for selecting the patients for conservative treatment, surgery or interventional radiology procedure.

Key words: **kidney • injury • trauma • computed tomography • ultrasound • embolization**

PDF file: http://www.polradiol.com/download/index/idArt/889780

Background

Renal injury occurs in approximately 8–10% of blunt or penetrating abdominal trauma [1,2]. The overwhelming majority (80–90%) of renal trauma involve blunt rather than penetrating injury [2]. 75–80% of major renal injuries are associated with penetrating or blunt trauma to other abdominal organs [3,4]. Our previous study demonstrated renal contusion in 19% of patients with pancreatic trauma [5]. The vast majority (98%) of isolated renal trauma is considered as minor injuries [6].

Generally accepted indications for kidney trauma imaging are: penetrating injury and hematuria, blunt trauma and gross hematuria, microscopic hematuria and hypotension, microscopic hematuria and significant associated injuries, direct contusion or hematoma of flank soft tissue, fractures of the lower ribs, transverse processes or dorso-lumbar spine [1,7,8]. However, there is a poor correlation between the severity of hematuria and the depth of renal injury [9]. Furthermore, the absence of hematuria does not preclude significant renal injury. The lack of hematuria was observed in up to 24% of cases of renal artery thrombosis [10] and one-third of pelvi-ureteric junction (PUJ) obstructions [11]. Therefore, proper and timely diagnosis based on imaging techniques is very important, since any delay in the diagnosis of renal injury can defer effective treatment and significantly increase the risk of morbidity and mortality [8].

Since the mid-1980s, CT has replaced intravenous urography and became the diagnostic tool of choice for the assessment of renal trauma and other asociated injuries [1,7,9]. In the setting of acute trauma, CT provides essential anatomic and physiologic information that can differentiate trivial injuries from those requiring intervention [1,7,9]. Furtermore, multislice fast CT technique with multiplanar and 3D image reformation offers new diagnostic possibilities in the setting of abdominal and renal trauma [1,5,7].

Ultrasound (US) provides several advantages in the evaluation of abdominal trauma, including minimal preparation, low cost, wide availability, portability and non-invasiveness [1,12]. US can easily identify free intraabdominal fluid, such as hemoperitoneum. However, it cannot reliably differentiate blood from extravasated urine or other body fluids [13,14]. Furthermore, with sensitivity as low as 22% [12,13], US has a limited capability in the evaluation of parenchymal renal injury when compared to a CT [7]

Since most vascular injuries can be assessed by a CT [1,7], angiography is now seldom used in the assessment of renal trauma. However, angiography with transcatheter embolization became an advantageous alternative to surgery for the control of active bleeding or secondary arterial hemorrhage, a common consequence of pseudoaneurysm or arteriovenous fistula [1,7,15,16].

Magnetic resonance imaging can be used for the assessment of suspected renal injury when there is contraindication for the intravascular use of iodinated contrast medium or when CT is not available [7,17].

The aim of the study

The purpose of this review is to illustrate and discuss the spectrum of imaging findings, particularly CT of blunt and penetrating renal trauma, based on own material and according to the AAST renal injury grading scale. The article also discusses the conditions in which interventional radiology procedures can be applied for the management of renal trauma.

Material and Methods

This pictorial review is based on selected cases from the imaging material collected at the Radiology Department of Hamad Medical Corporation during a 14-year period from 1999 to 2012. The material includes 176 cases with confirmed blunt or penetrating renal trauma. Out of 1,484 abdominal trauma cases, 176 patients (164 males and 12 females) were confirmed to have had kidney injury. The age range was 10–60 years (mean age 23 years). The causes of renal trauma in our material were: motor vehicle accidents – 98, bicycle accidents – 3, falls from height – 49, contact sports – 2, domestic violence/assaults – 1, hits by a heavy object – 5, stab wounds – 3, iatrogenic injury – 15.

The most representative cases of renal trauma were reviewed according to the spectrum of CT findings and categorized according to the AAST grading system [1].

Two groups of patients were discussed separately: those with preexisting renal abnormalities and those with sustained iatrogenic renal injury.

Following abdominal trauma, all patients had a CT examination performed on admission to the hospital and/or during hospitalization.

Patients were examined using a 4-slice, 16-slice and most currently 64-multislice CT (Sensation 64, Siemens Germany). A spiral acquisition volume covered the chest, abdomen and pelvis with an 8 mm collimation, followed by a 2 mm reconstruction and multiplanar reformatting. In adults, scanning usually started with a delay of 50-70 seconds from the time of intravenous (IV) administration of 110–130 ml of non-ionic contrast medium (Iohexol 300 mg Iodine/ml, Schering, Germany) at an injection rate of 2–3 ml/sec. Total injected volume and injection rate were adjusted according to the patient's age, weight, estimated cardiac output and size of the cannula through which the injection was given. Additionally, abdominal scanning was repeated 7–10 minutes from the beginning of IV contrast administration to register renal excretory phase.

Occasionally, some patients had US examination performed at the admission and during follow up.

Pictorial Review

Various classifications of renal injury were proposed in the past. They were based on pathogenesis, pathomorphologic findings and clinical parameters [1]. Two of the most popular ones are: radiologic classification [7] and more recently, the AAST grading system for renal injury [1].

Currently, the AAST grading system for renal injury is most widely used and accepted [1]. It is based on surgical findings and is useful for the prediction of clinical outcome in patients with renal trauma [18–22]. It is composed of 5 grades (I–V) arranged in order of increasing severity according to the depth of injury, involvement of the renal vascularity and collecting system (Table 1). It correlates well with CT findings [1].

Grade I injuries

This is the most common type of renal injury (75–85% of cases) [1,7,9,13,14,21,23–25] and includes organ contusion with microscopic or gross hematuria with normal imaging findings and cases of non-expanding subcapsular hematomas with no parenchymal laceration. Contusion is commonly demonstrated on a CT as a focal area of decreased contrast enhancement of renal parenchyma, frequently ill-defined, round or ovoid in shape [1,7,9,13,14,16,21,23–25] (Figure 1). Contusions may also appear as focal areas of striation on nephrograms or persistent contrast material straining on delayed nephrograms [7]. They may sometimes show well-delineated margins and may even appear as hyperattenuating areas once blood clots fill the injured area on pre-contrast images [16].

Table 1. AAST Renal Injury Scale.

Grade*	Type of Injury	Description
I	Normal contusion Hematoma	Microscopic or gross hematuria with normal urologic findings Nonexpanding subcapsular hematomas with no laceration
II	Hematoma Laceration	Nonexpanding perinephric (perirenal) hematomas confined to the retroperitoneum 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 Vascular injury**	Renal lacerations extending through the renal cortex, medulla, and collecting system Injuries involving the main renal artery or vein with contained hematoma, segmental infarctions without associated lacerations
V	Laceration Vascular injury	Shattered kidney, ureteropelvic junction avulsions 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 [1].

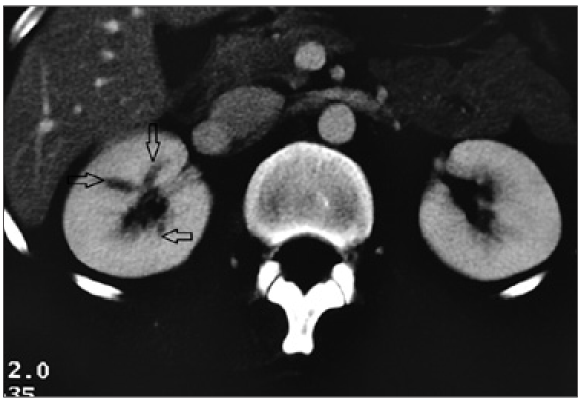

Figure 1. Male, 46-year-old, blunt abdominal trauma. Renal contusion (focal intrarenal hematoma). CT: focal areas of decreased contrast enhancement in the mid-cortex of the right kidney (arrows).

Grade I renal injury also includes non-expanding subcapsular hematomas without parenchymal laceration (Figure 2A, 2B).

Contusion should be differentiated from (sub) segmental infarction. The latter appears as a well-demarcated, wedge-shaped area of decreased contrast enhancement (Figure 3). (Sub) segmental infarction is usually the consequence of stretching and thrombotic occlusion of an accessory renal artery, capsular artery or intrarenal subsegmental branch [7]. Subsegmental infarction may result in a renal scar [7].

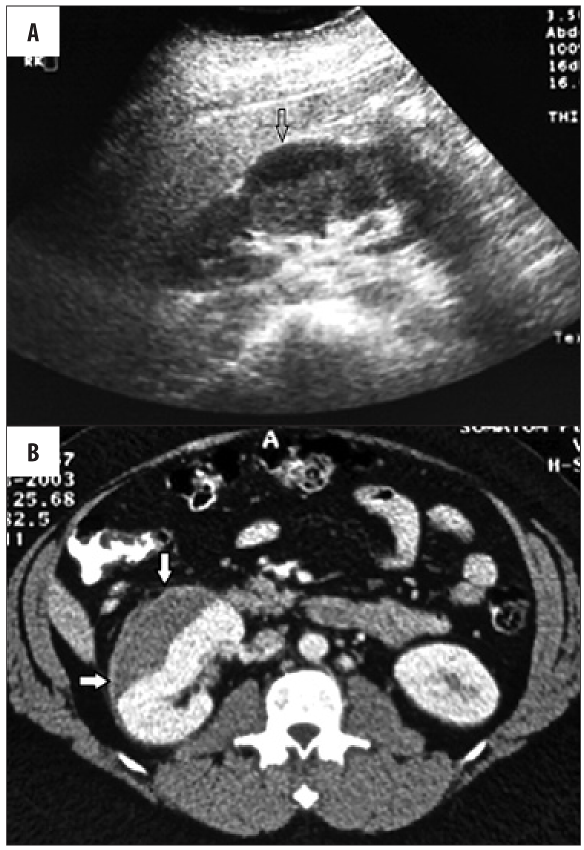

Figure 2. Male, 35-year old, road traffic accident. Subcapsular hematoma. (**A**) – Ultrasound: hypoechoic crescent area in the mid portion of the kidney (arrow), (**B**) – CT: hypodense subcapsular collection (arrows).

Grade II injuries

Grade II injuries include nonexpanding perinephric/perirenal hematomas confined to the retroperitoneum, as well as superficial cortical lacerations measuring less than 1 cm without affecting the collecting system [1]. Perinephric or perirenal hematoma is usually poorly outlined, hyperattenuating (45–90 HU) collection that is confined between the kidney and the Gerota's fascia [1,9,16,23,24]. Thickening of the lateroconal fascia, displacement of the kidney and compression of the colon were also observed [16]. Renal parenchyma lacerations demonstrate as hypoattenuating, wedge-shaped or linear defects [1,7,14,16,24], (Figure 4). In a case where laceration is filled with blood clot, it becomes hyperdense to the surrounding renal parenchyma in unenhanced scans.

Figure 3. Male, 47-year old, blunt abdominal trauma. Subsegmental infarction. CT: wedge-shaped area of decreased attenuation in the interpolar region of the right kidney (arrow).

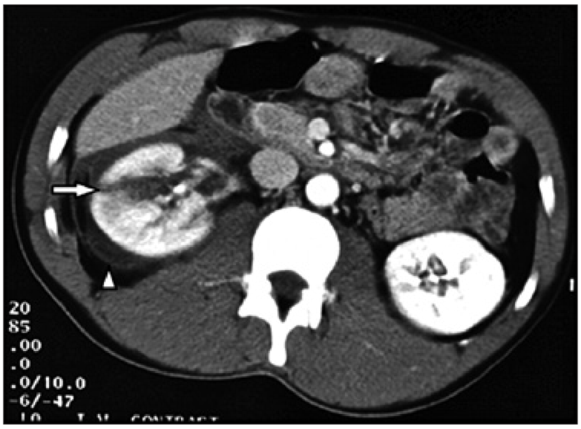

Figure 4. Female, 30-year-old, blunt abdominal trauma. Small cortical laceration. CT: laceration in the interpolar region (arrow) of the right kidney with a small perinephric hematoma (arrowhead).

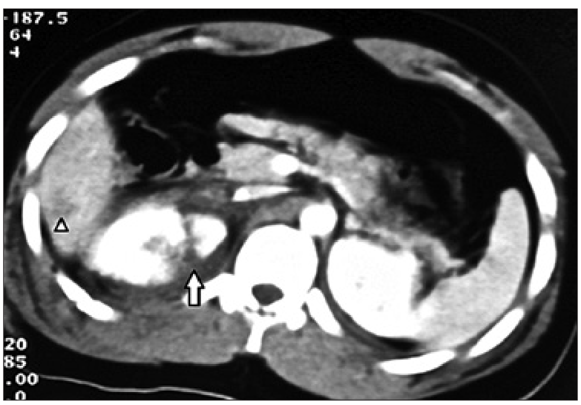

Figure 5. Male, 16-year-old, road traffic accident. Major renal laceration through the cortex extending to the medulla without involvement of the collecting system. CT: large subcapsular hematoma with corticomedullary laceration of the right kidney (arrow), sub-hepatic fluid and liver contusion, segment VI (arrowhead).

Grade III injuries

Grade III injuries include renal lacerations greater than 1 cm, but without the collecting system involvement [1], (Figures 5 and 6).

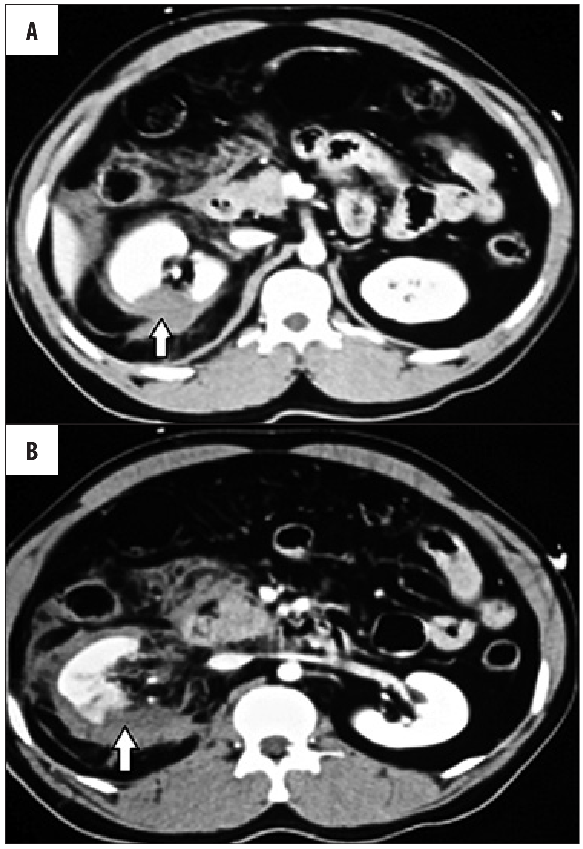

Figure 6. (**A, B**) Male, 32-year-old, road traffic accident. Major renal laceration through the cortex extending to the medulla without involvement of the collecting system. CT: large sub-capsular hematoma, complete renal laceration of the right kidney (arrow).

Grade IV injuries

Grade IV injuries include deep parenchymal lacerations extending through the renal cortex and medulla into the collecting system (Figure 7A–7E), injuries involving the main renal artery or vein with contained hemorrhage (Figure 8A, 8B) and segmental infarctions without associated lacerations [1]. Thrombosis of the main renal artery is the most significant vascular injury following blunt trauma [26,27]. Deceleration causes stretching and tearing of the intima, which is less elastic than the media and adventitia [28]. The resultant intimal flap initiates thrombosis, which quickly propagates distally [28]. Complete infarction is less common than segmental or subsegmental infarction in patients sustaining blunt trauma [7]. Non-visualization of the kidney is consistent with thrombosis of the main renal artery [7]. The cortical rim sign is produced by a thin capsular or subcapsular enhancement as a result of collateral circulation through capsular, peripelvic and periuretric vessels [29]. The cortical rim sign usually appears from 8 hours to several days after the injury [29,30]. The same deceleration mechanism may lead to the formation of dissecting aneurysm of the main renal artery, its branch or renal artery stenosis, which may result in the development of post-traumatic renovascular hypertension [31]. When laceration extends into the renal collecting system, extravasated contrasting urine may be seen during the

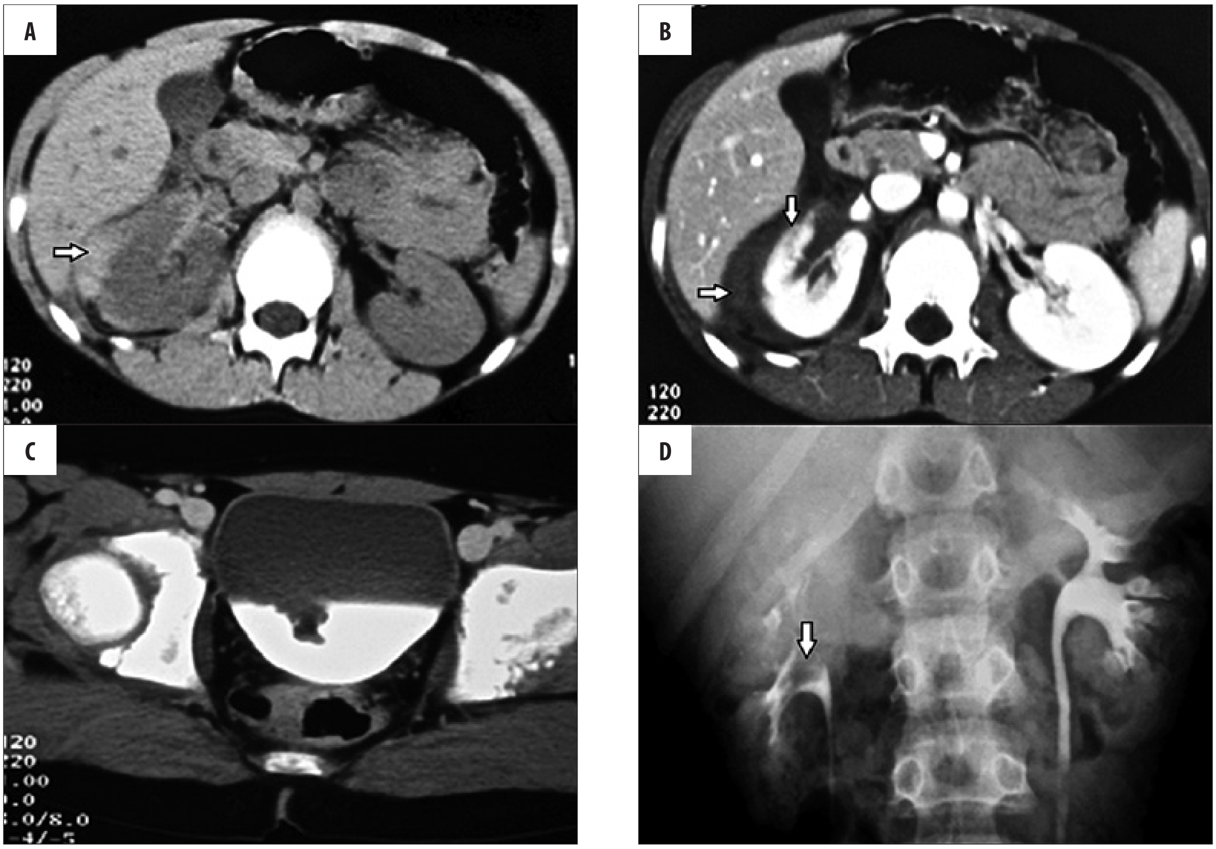

Figure 7. Male, 12-year-old, fall from a staircase. Deep parenchymal laceration involving collecting system. (**A, B**) – unenhanced and post-contrast CT: large sub-capsular hematoma, intrarenal hematoma and corticomedullary laceration of the right kidney with hyperdense presentation of blood in unenhanced scans (**A**) and hypodense in post-contrast scans (**B**), (arrows). (**C**) – CT: filling defect within the urinary bladder due to blood clot. (**D**) – Urography: filling defect in the right renal pelvis due to blood clot (arrow).

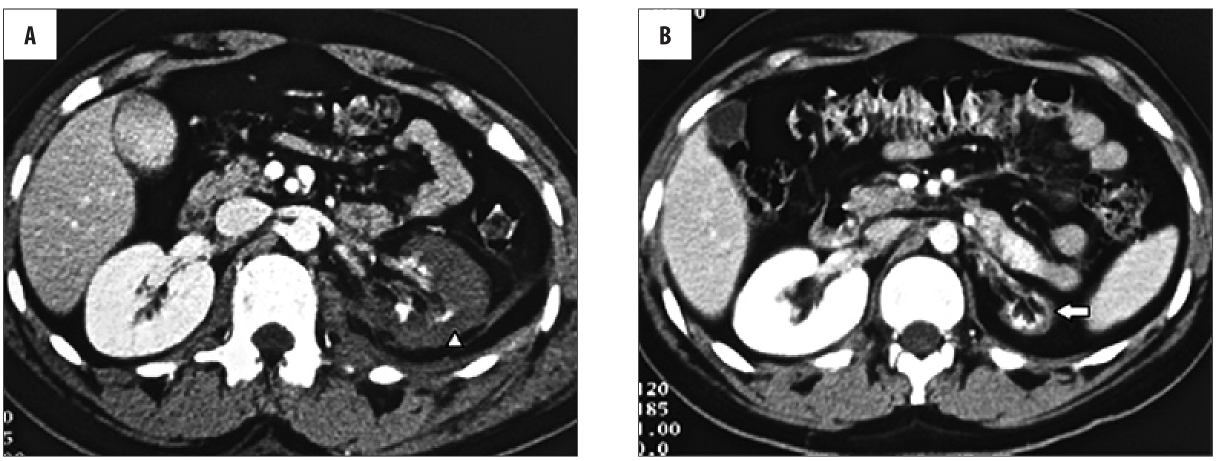

Figure 8. Male, 22-year old, road traffic accident. Traumatic occlusion of the main renal artery. (**A**) – CT: intimal renal artery injury with thrombosis and infarction, lack of perfusion of the left kidney (arrowhead). (**B**) – CT: follow up after 5 months: post-infarction atrophy of the left kidney (arrow).

pyelographic phase of the CT within a tear or around the kidney [7,9,13,16]. Delayed scanning 10–15 minutes after intravenous administration of contrast medium may be useful in selected patients to display the extent of urinary extravasation [9].

Grade V injuries

Grade V injuries are the most severe and include lacerations that completely shatter the kidney, PUJ avulsion (Figure 9A, 9B), complete laceration (avulsion) or thrombosis of the main renal artery or vein that devascularizes the kidney [1,9]. The term "shattered kidney" refers to gross renal parenchyma disruption by multiple lacerations. These

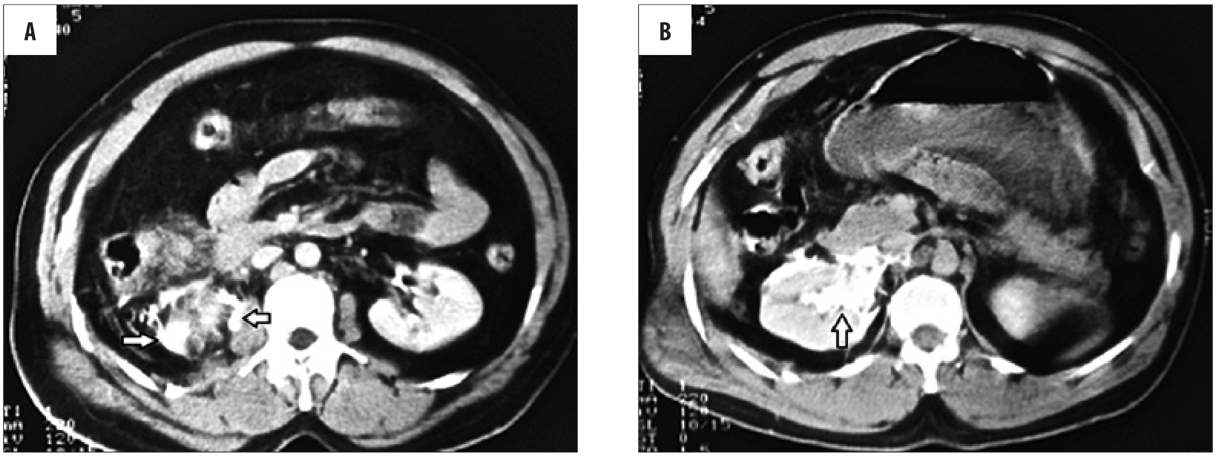

Figure 9. Male, 43-year-old, blunt abdominal trauma. Avulsion of the pelvi-ureteric junction. (**A**) – CT: extravasated contrast medium (arrows), (**B**) – CT excretory phase: extravasated urine with contrast medium (arrow).

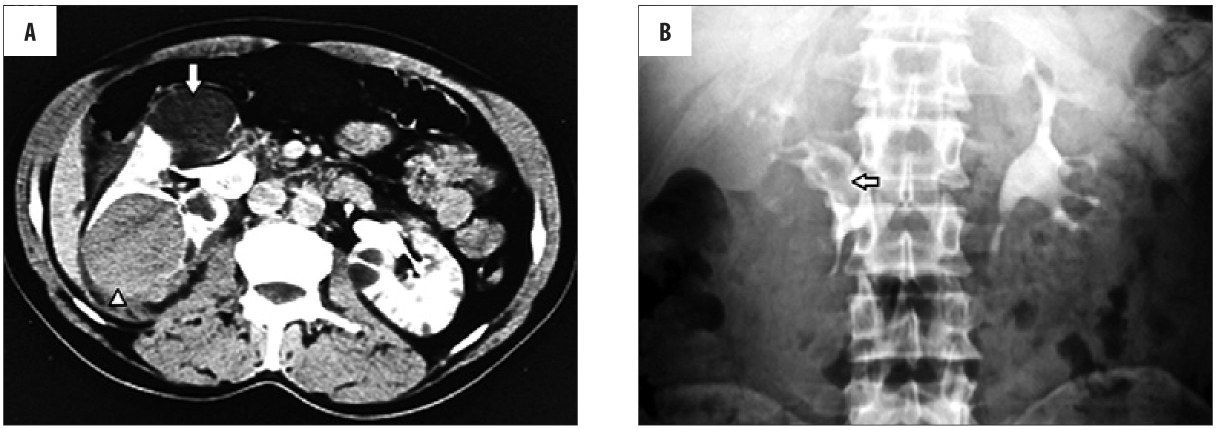

Figure 10. Male, 35-year-old, road traffic accident, Traumatic injury to the kidney with multiple cysts. (**A**) – CT: bleeding into the cyst – increased attenuation (arrowhead), compared to the unaffected cyst (arrow). (**B**) – Urography: filling defects (blood clots) in the right renal pelvis (arrow).

Figure 11. Male, 30-year old, road traffic accident. Traumatic injury to a horseshoe kidney with a stone in the right renal pelvis. (**A**) – CT (axial): subcapsular hematoma and extravasation of contrast medium (arrows) and stone in renal pelvis (arrowhead), (**B**) – CT (coronal reformation).

injuries are frequently associated with multiple areas of renal infarction [9]. Devascularization of the kidney due to laceration or thrombosis of the main renal artery constitutes the most severe form of renal injury [9]. Classic CT

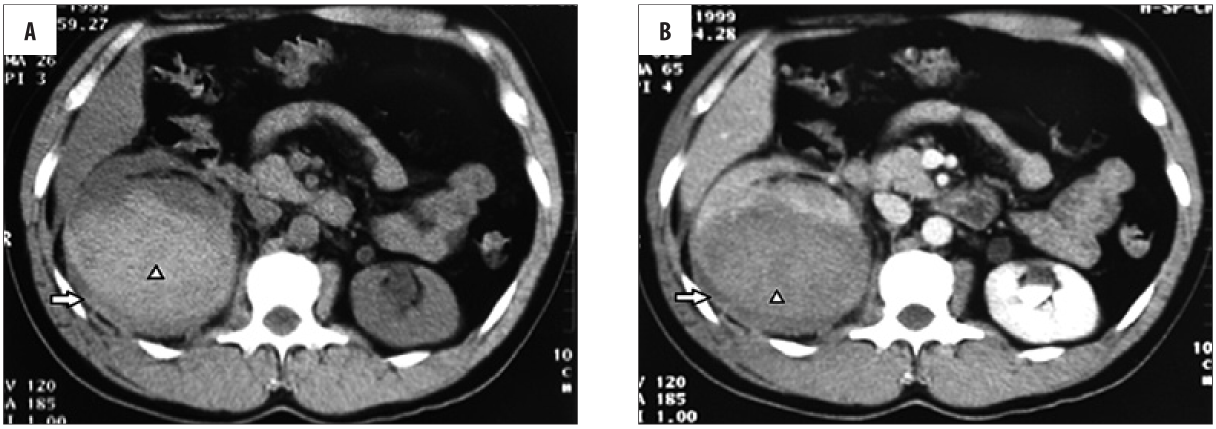

Figure 12. Male, 32-year-old, post-lithotripsy for a right kidney stone. (**A, B**) – unenhanced and enhanced CT: subcapsular hematoma (arrow), intrarenal hematoma (arrowhead).

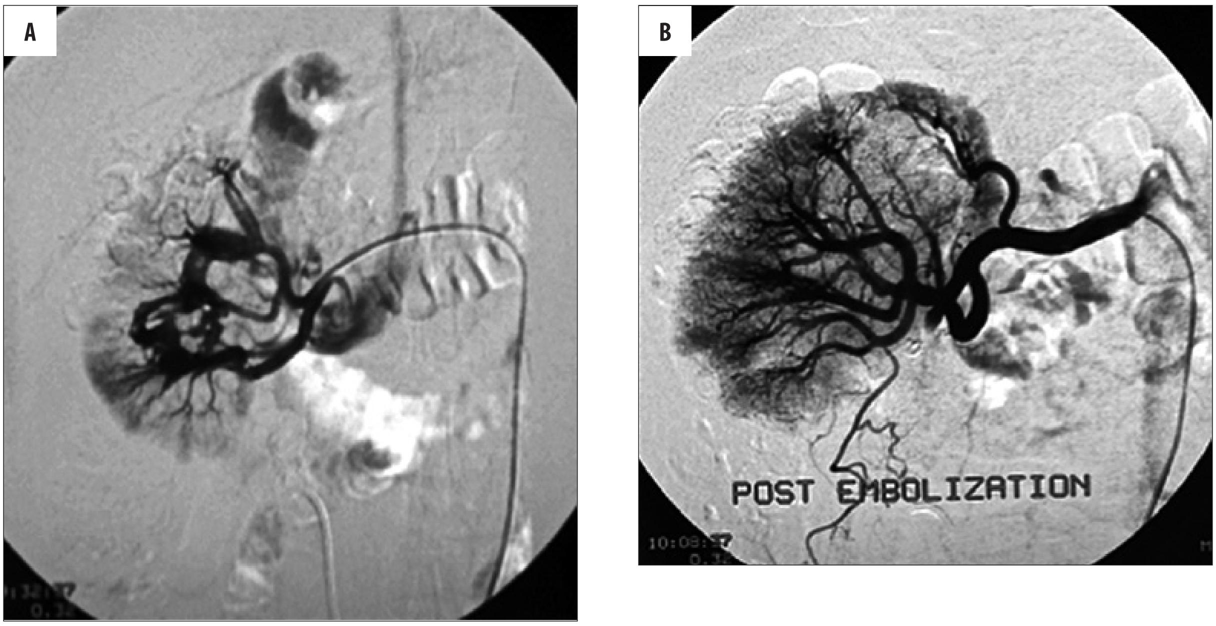

Figure 13. Male, 45-year-old, post percutaneous nephrolithotomy for staghorn calculus resulting in a large subcapsular hematoma and corticomedullary laceration. (**A**) – angiography: arterio-venous fistula formation at the segmental artery of the ventral branch of the right renal artery, early visualization of the renal vein. (**B**) – status post-embolization with tornado coils – no flow through the arterio-venous fistula.

presentation of traumatic renal infarction includes absent nephrogram on the affected side, retrograde opacification of the renal vein from the inferior vena cava and abrupt truncation of the renal arterial lumen at the point of occlusion [32]. Avulsion of the renal artery is a rare, but life-threatening condition caused by laceration of the tunica muscularis and adventitia [7]. CT reveals total infarction of the kidney associated with extensive medial perirenal hematoma [23]. Active arterial bleeding may also be seen [7].

Injuries to the Kidneys with Preexisting Abnormalities

The AAST renal injury scale is based on kidney appearance during surgery and does not include anomalies related to kidney anatomy and various pathological conditions. Such situations are quite common and therefore should be discussed separately. Preexisting renal abnormalities predispose the kidneys to an increased risk of injury and a lower probability of renal salvage following blunt abdominal trauma [1,7,16]. The most common traumatic situations in kidneys with preexisting abnormalities include: disruption of PUJ in the setting of hydronephrosis, intracystic hemorrhage or rupture of a renal cyst with/without communication with the collecting system (Figure 10A, 10B), rupture of a polycystic kidney or renal tumor, laceration of an ectopic, horseshoe kidney (Figure 11A, 11B), transplanted or infected kidney, as well as in hemophilia, blood coagulation disorders and in patients receiving anticoagulation therapy [1,7,16,33].

Iatrogenic Injury

In the hospital practice, renal trauma can be the result of diagnostic or therapeutic procedures, such as needle biopsy, percutaneous nephrostomy and extracorporeal shock wave lithotripsy (Figures 12–14), or intraabdominal surgery. These

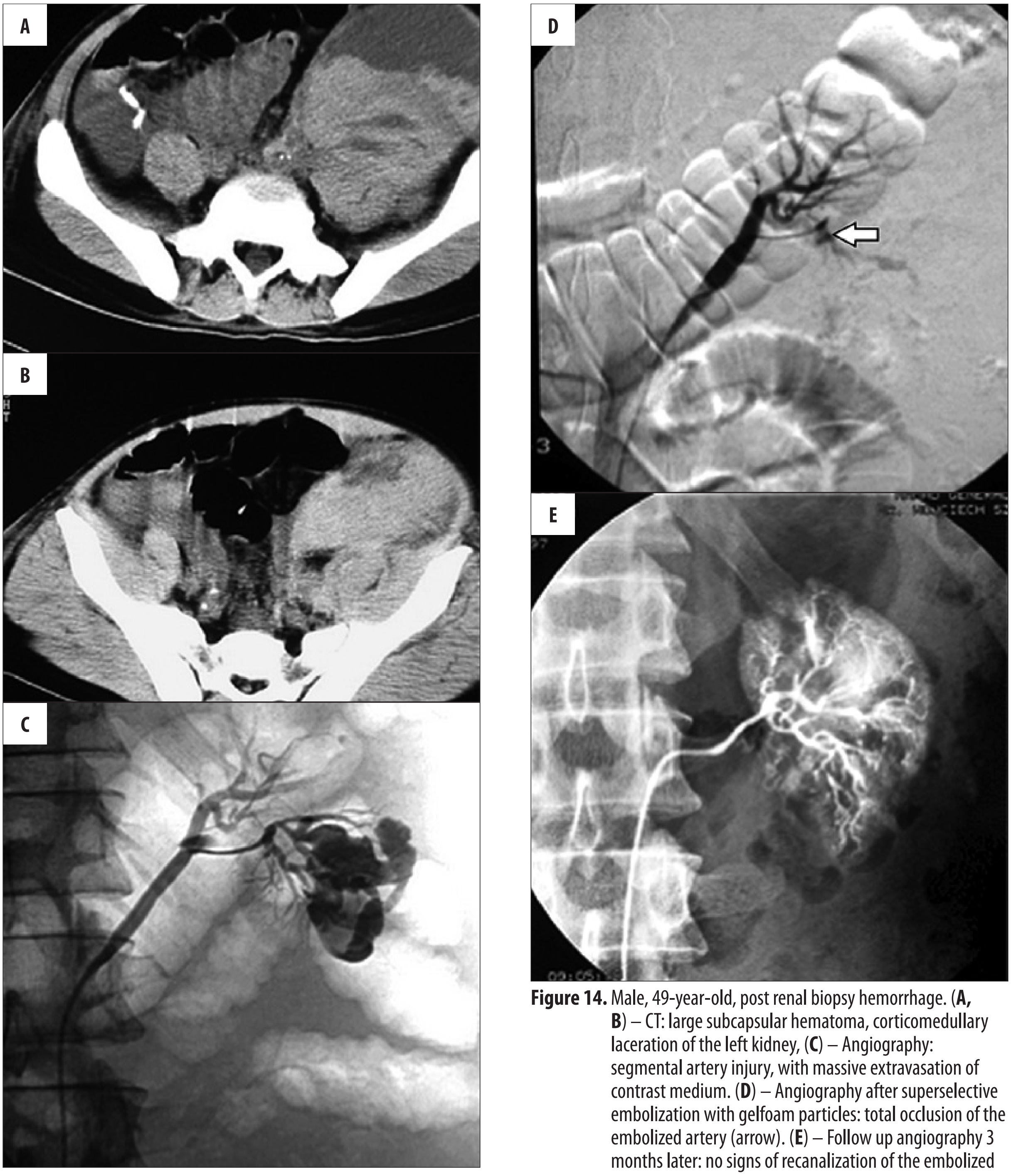

Figure 14. Male, 49-year-old, post renal biopsy hemorrhage. (**A, B**) – CT: large subcapsular hematoma, corticomedullary laceration of the left kidney, (**C**) – Angiography: segmental artery injury, with massive extravasation of contrast medium. (**D**) – Angiography after superselective embolization with gelfoam particles: total occlusion of the embolized artery (arrow). (**E**) – Follow up angiography 3 months later: no signs of recanalization of the embolized artery.

iatrogenic injuries can result in renal hematoma, laceration, pseudoaneurysm and arteriovenous fistula [7,24]. Since the 1980's, transcatheter arterial embolization has become an established therapeutic procedure in the control of renal hemorrhage [34], including post-surgical and iatrogenic [15].

Complications of Renal Trauma

The knowledge of potential complications of renal trauma and their imaging manifestations is very important for a radiologist, since it may determine the patient's management. Complications occur in a wide range from 3% to 33% of all renal trauma cases [7,16,35]. Early complications usually occur within 4 weeks and include: urinary extravasation or urinoma, delayed bleeding, infected urinoma, development of perinephric abscess, sepsis, pseudoenurysm, A-V fistula and hypertension [7,36,37]. Late or delayed complications of renal trauma include hydronephrosis, hypertension, calculus formation or chronic pyelonephritis [24,31,35–37]. Late complications are more common when renal trauma had resulted in devascularized parenchymal fragments [36].

Conclusions

Based on the review of own material, as well as data from the literature, it can be concluded that proper application of renal trauma grading scale is essential for the selection of patients for conservative treatment, surgery or interventional radiology procedures.

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