Shattering Kidneys: Review of CT Imaging Features of Severe Renal Injuries from Blunt Trauma

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Authors: D. Gai, H. Knipe, P. Phal; Melbourne/AU
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Learning objectives

The kidneys are highly vascular, paired viscera involved in homeostasis and excretion of waste. They are among the more common solid organs to be injured in blunt trauma. Our poster describes the CT imaging appearances and grading of severe renal injuries resulting from blunt trauma.
Background

The kidneys are highly vascular, paired viscera involved in homeostasis and excretion of waste. Renal injury is found in 8-10% of blunt and penetrating abdominal trauma. Of these, 90% are caused by road traffic accidents or sporting injuries. The recognition of several different injuries allows for accurate grading. In particular, massive renal parenchymal laceration or renovascular compromise are indicators of severe (Grade IV and V) renal injury. In conjunction with the patient's clinical status, accurate imaging grading of severe renal injury can aid in determining between surgical or conservative management.
Imaging findings OR Procedure details

Normal renal anatomy

The kidneys are paired, bean-shaped organs located in the retroperitoneum. They are a key component of the urinary system, and also have important homeostatic functions. The kidneys are surrounded by a renal capsule, perinephric fat and most superficially, a layer of renal fascia (Gerota’s fascia). The hilum of the kidneys face medially and contain the renal vein, artery and pelvis, from anterior to posterior.

The renal arteries are large calibre and deliver over 1 litre of blood flow to the kidneys per minute. The arterial anatomy is quite variable but we describe the classical configuration. Each kidney possesses five segments (apical, upper, middle, lower, posterior) and the renal arteries provide segmental supply. At the hilum, the renal artery gives rise to an anterior and posterior division. The posterior division supplies the posterior segment, while the anterior division supplies the apical, upper, middle and lower segments.

The renal vein is the confluence of five or six small vessels that have united at the hilum to form a single renal vein. It drains blood that has been filtered by the glomerular system of the kidney. The right renal vein is short and drains to the inferior vena cava, while the left renal vein is longer as it must cross the aorta. The left renal vein also has the left gonadal and suprarenal vein draining into it.

The renal pelvis is the commencement of the ureter as it descends to the trigone of the bladder. It is formed by the confluence of 2-3 major calyces. It is lined by transitional epithelium which overlies smooth muscle, which causes it to make contractile waves passing down the ureter.

The internal structure of the kidney is divided into a deep medulla, surrounded by superficial cortex. The functional unit of the kidney is a nephron, consisting of a glomerulus and a tubule system. Blood is filtered by the glomerulus and the resulting ultrafiltrate continues to be filtered by the tubular system. The final urine product is collected into the collecting ducts and drain via minor and major calyces to the renal pelvis.

Renal contusion
Renal contusions (Fig. 1 on page 8), in isolation, are a sign of low grade injury (Grade I AAST). Pathologically, contusions represent ruptured capillaries within the renal parenchyma. They can be considered as small intrarenal haematomas. Importantly, they may be separate from parenchymal tearing (see renal laceration, below). Blood lost via ruptured capillaries leads to microscopic or macroscopic haematuria.\(^3\)

Imaging studies can be normal, or they may appear as ill-defined, round or ovoid hypoattenuating areas relative to the adjacent normal enhancing parenchyma. The margins may be sharp or poorly defined. Renal contusions are self-limiting and are managed conservatively.

**Renal haematoma**

Renal haematoma represents either Grade I or Grade II AAST injury. A haematoma is a collection of blood, outside the vascular system and can be divided into subcapsular or perirenal subtypes.

Subcapsular haematoma (Fig. 2 on page 8) collects deep to the tight renal capsule. It does not extend outside of this capsule and does not involve the perinephric fat. The renal capsule acts as a rigid container to tamponade the haematoma.

Perirenal haematoma (Fig. 3 on page 9) is a more severe type of injury, where there has been breach of the renal capsule and the resulting haematoma has escaped into the perinephric fat. The renal fascia still contains the haematoma within the retroperitoneum. This type of injury is a Grade II AAST injury.

On CT, subcapsular haematomas appear as round or elliptic hyperattenuating (40-60HU) fluid indenting the margins of the kidney, without extracapsular extravasation. Older haematomas may appear iso or hypodense depending on the age. Perirenal haematomas tend to be larger and demonstrate capsular invasion. There is no contrast enhancement.

**Renal laceration**

A laceration (Fig. 4 on page 10) is a tear of the renal parenchyma (renal cortex and/or medulla). Smaller lacerations may involve a small amount of parenchyma and be self-limiting. Larger lacerations may also involve important renal structures and compromise kidney function. Structures that may be involved include:\(^4\):

- collecting system and calyces (Fig. 5 on page 11)
• renal pelvis and ureter
• renal vasculature

Renal lacerations appear as linear, hypoattenuating areas in the parenchyma. They do not usually enhance with contrast as they contain clotted blood. Lacerations can be classified as superficial (<1 cm in depth) or deep (>1 cm in depth). Multiple deep lacerations may be associated with 'shattered kidney', a grade V injury (Fig. 9 on page 15).

**Renal pseudoaneurysm**

Renal pseudoaneurysms (Fig. 6 on page 12) can arise from traumatic and iatrogenic events. Renal arterial trauma may cause adjacent haematoma formation just outside the arterial wall. The haematoma is then surrounded by a layer of fibrous inflammatory tissue. This unstable layer can rupture, causing life threatening haemorrhage.

Acutely, CT may show only renal parenchymal laceration without pseudoaneurysm due to acute thrombus sealing the laceration. Subsequently, the thrombus may lyse, giving the typical pseudoaneurysm appearance with arterial phase enhancement and delayed phase washout.

**Renal arteriovenous fistula**

Renal arteriovenous fistulas (Fig. 7 on page 13) are divided into either congenital or acquired subgroups. They are an abnormal connection directly between renal artery and renal vein. In the acquired group, this is most often following renal biopsy but can also arise from blunt trauma.

On CT angiography, early enhancement of a vein can be suggestive of fistulation from an adjacent arterial source.

**Renal hilum avulsion**

Avulsion of the renal hilum is universally classified as a grade V injury. Renal hilum avulsion involves complete tearing of the renal artery, vein and ureter leading to renovascular compromise (Fig. 8 on page 14).

CT angiography reveals a complete hypodense kidney, with renal haematoma lying at the medial border of the compromised kidney. Hyperdense blood in the perirenal space
may also be seen, representing active arterial bleeding from the renal artery\(^8\). This most severe injury can also be associated with 'shattered kidney' (Fig. 9 on page 15).

**Differentiating between grade 4 and 5 injuries**

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<tr>
<th></th>
<th>Grade IV Injury</th>
<th>Grade V Injury</th>
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<tbody>
<tr>
<td>Laceration extending through renal cortex, medulla and collecting system</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of extensive lacerations</td>
<td>Single</td>
<td>Multiple</td>
</tr>
<tr>
<td>Renal vascular injury</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
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<td>Yes</td>
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<tr>
<td>Renal devascularisation</td>
<td>No</td>
<td>Yes</td>
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**Fig. 1:** Right lower pole contusion (white arrow), which on CT is represented by an ill-defined cortical hypodensity.

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Fig. 2: Right sided subcapsular haematoma. There is a homogeneous hypodense segment on the lateral border of the right kidney in this delayed phase CT.

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Fig. 3: Renal laceration with perirenal haematoma. There is fluid (55 HU) extending through the posteroinferior renal cortex and medulla, with extension into the perirenal space.

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Fig. 4: Left lower pole laceration. There are two lacerations in the posteromedial left kidney with haematoma lying dependently.

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**Fig. 5:** Left sided collecting system injury. Hyperdense contrast is escaping from the pelvo-ureteric junction into the surrounding retroperitoneum.

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Fig. 6: Right inferior pseudoaneurysm. Black arrow indicates the pseudoaneurysm, which is the same density as the surrounding blood vessels on both arterial and portal venous phase imaging.

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**Fig. 7:** Left renal arteriovenous fistula (blue arrow indicates early venous filling) subsequently confirmed on digital subtraction angiography.

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**Fig. 8:** Devascularisation of right kidney (Grade V injury). The right kidney is hypodense compared with the normally perfused left kidney.

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**Fig. 9:** Shattered kidney (Grade V injury). There are multiple, complete lacerations through the left kidney with minimal perfusing parenchyma and massive perirenal haematoma.

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**Table 1:** Differentiating between Grade IV and V renal injuries can be done by assessing the degree of laceration and devascularisation.

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Conclusion

Severe renal injuries can result in serious morbidity and mortality. Recognition of the array of injuries as well as accurate grading on CT is important in the management of trauma patients.
Personal information

Department of Radiology, The Royal Melbourne Hospital.
References


