Ther Adv Urol
2018, Vol. 10(10) 295–303
DOI: 10.1177/1756287218785828

Renal trauma: the current best practice

Tomer Erlich and Noam D. Kitrey

Abstract: The kidneys are the most vulnerable genitourinary organ in trauma, as they are involved in up to 3.25% of trauma patients. The most common mechanism for renal injury is blunt trauma (predominantly by motor vehicle accidents and falls), while penetrating trauma (mainly caused by firearms and stab wound) comprise the rest. High-velocity weapons impose specifically problematic damage because of the high energy and collateral effect. The mainstay of renal trauma diagnosis is based on contrast-enhanced computed tomography (CT), which is indicated in all stable patients with gross hematuria and in patients presenting with microscopic hematuria and hypotension. Additionally, CT should be performed when the mechanism of injury or physical examination findings are suggestive of renal injury (e.g. rapid deceleration, rib fractures, flank ecchymosis, and every penetrating injury of the abdomen, flank or lower chest). Renal trauma management has evolved during the last decades, with a distinct evolution toward a nonoperative approach. The lion's share of renal trauma patients are managed nonoperatively with careful monitoring, reimaging when there is any deterioration, and the use of minimally invasive procedures. These procedures include angioembolization in cases of active bleeding and endourological stenting in cases of urine extravasation.

Keywords: hematuria, kidney injury, multiple trauma, renal injury

Received: 12 July 2017; accepted in revised form: 7 June 2018.

Correspondence to:
Noam D. Kitrey
Department of Urology, The Chaim Sheba Medical Center, 2 Sheba Road, Tel Hashomer, 5262100, Israel
nkitrey@gmail.com

Tomer Erlich
Department of Urology, The Chaim Sheba Medical Center, Tel Hashomer, Israel

Background

Renal trauma management has evolved during the last decades, with a clear transition toward a nonoperative approach.[1–4] This transition is probably derived from a combination of several aspects. First, the accumulative knowledge about the safety and outcome of the renal trauma nonoperative approach,[1–17] and also for the management of other internal organs like the spleen and liver.[18–21] Second, the improvement in imaging modalities [mainly computed tomography (CT) scanning][22] and in minimally invasive treatment techniques. These techniques include angioembolization in cases of active bleeding,[23–25] and endourological stenting in cases of urine extravasation.[22,26,27] The purpose of this review is to present the current best practice management of renal trauma.

Epidemiology, etiology and pathophysiology

Epidemiology

Despite its relatively protected retroperitoneal position, the kidney is the most commonly injured organ of the genitourinary system during trauma.[28] Renal trauma can be an isolated injury but in 80–95% of cases there are concomitant injuries.[16,29,30] Renal trauma affects predominantly men, 72–93% of cases,[3,5,31,32] and it is more frequent in the young population with a mean age range from 31 to 38 years.[5,16,17] The mean age is even younger when only penetrating trauma is included (27–28 years).[6,30]

The prevalence of renal trauma among trauma patients ranges from 0.3% to 3.25%,[12,17,33–36] and the most common mechanism for renal injury is blunt trauma. Blunt renal trauma accounts for 71–95% of renal trauma cases.[5,12,23,26,32–35]

Etiology and pathophysiology of blunt renal trauma

In a systematic review conducted by Voelzke and Leddy, blunt renal trauma in the adult population was caused primarily by motor vehicle accidents (MVAs) (63%), followed by falls (43%), sports (11%) and pedestrian accidents (4%), while blunt trauma in the pediatric population was caused by more falls (27%) and pedestrian accidents (13%) and fewer MVAs (30%).[31] In another review of the pediatric trauma registry, McAleer and colleagues found that pediatric renal blunt trauma was caused by bicycling (28%), falls (23%), all-terrain vehicle riding (8%), playground (8%), motorcycling (6%), team sports (6%), rollerblading (6%), playing ball (4%), equestrian sports (3%) and trampoline jumping (1%); no kidneys were lost in this study.[37]

The pathophysiology of blunt renal trauma is not completely understood but it seems that the major elements that cause the trauma are deceleration and acceleration forces. The kidney is covered by fat and the Gerota facia in the retroperitoneum, and the renal pedicle and uretero-pelvic junction (UPJ) are the major attachment elements; therefore, deceleration forces on these elements may cause renal injury like rupture or thrombosis.[38] Acceleration forces may cause collision of the kidney in its surrounding elements, like the ribs and spine, and cause parenchymal and vascular injury.[38]

Abnormal kidneys that were found in 7% of the patients with blunt renal trauma are frequently injured by low-velocity impacts; nevertheless, contrast studies should be generously indicated, since the management of abnormal kidneys unmasked by trauma is largely dependent on the type of pathology.[39] Schmidlin and colleagues found that pre-existing kidney abnormalities included hydronephrosis (38%), cysts (17%), tumor (7%), ectopic kidney (7%) and others (31%).[39] According to a computer-simulated model, a liquid-filled incompressible compartment appears to amplify the force of the trauma impact, and therefore may explain the higher vulnerability of an abnormal kidney with hydronephrosis or a cyst.[40]

Etiology and pathophysiology of penetrating renal trauma

Most penetrating renal traumas, which are more severe and less predictable than blunt traumas, are caused by firearms (83–86%) and stab wound (14–17%).[6,30] In combat scenarios, various kind of fragments [e.g. improvised explosive devices (IEDs) and other shrapnel] also cause penetrating renal trauma. Penetrating trauma is classified according to the velocity of the projectile: high-velocity projectiles (e.g. rifles), medium velocity (e.g. handguns) and low velocity (e.g. knife stab). High-velocity weapons inflict greater damage because the bullets transmit large amounts of energy to the tissues. They form a temporary expansive cavitation that immediately collapses and creates shear forces and destruction in a much larger area then the projectile tract itself. Cavity formation disrupts tissue, ruptures blood vessels and nerves, and may fracture bones away from the path of the missile. In lower velocity injuries, the damage is usually confined to the track of the projectile.

The position of a stab wound affects its management. A stab wound to the anterior abdomen may injure vital renal structures like the renal pelvis and the vascular pedicle, while a stab wound posterior to the anterior axillary line will injure the parenchyma but less likely the vital renal parts.[41]

Classification and injury severity

The most common renal trauma classification is the American Association for the Surgery of Trauma (AAST) classification (Figure 1), an anatomic description, scaled from 1 to 5, representing the least to the most severe injury.[42]

The AAST classification was validated by five studies.[29,36,43–45] The AAST grade of renal injury, the overall injury severity of the patient, and the requirement of blood transfusion were the primary factors in determining the patient's need for nephrectomy[36,45] and overall outcome.[36,43] The AAST grade is a predictor for morbidity in blunt and penetrating renal injury, and for mortality in blunt injury.[44] The AAST grade has a statistically significant correlation with the need for surgery (from 0 to 93%) and for the risk for nephrectomy (0–86%).[29] Moreover, patients with gunshot injury have higher AAST grades than those with blunt trauma.[45]

A substratification was proposed by Dugi and colleagues in 2010.[46] They divided grade 4 into 4a (low risk) and 4b (high risk) according to three CT findings that were associated with the need for urgent intervention: perirenal hematoma rim distance larger than 3.5 cm, intravascular contrast extravasation, and medial renal laceration. They found that patients with zero to one risk factors (4a) were at low risk for intervention (7.1%), while those with two to three risk factors (4b) were at remarkably higher risk 66.7%.[46] Another revision was proposed by Buckley and colleagues in 2011.[47] According to the proposed definition, grade 4 injury includes all collecting system, renal

Grade*	Type of injury	Description of injury
I	Contusion	Microscopic or gross hematuria, urologic studies normal
	Hematoma	Subcapsular, nonexpanding without parenchymal laceration
II	Hematoma	Nonexpanding perirenal hematoma confirmed to renal retroperitoneum
	Laceration	<1.0 cm parenchymal depth of renal cortex without urinary extravagation
III	Laceration	>1.0 cm parenchymal depth of renal cortex without collecting system rupture or urinary extravagation
IV	Laceration	Parenchymal laceration extending through renal cortex, medulla, and collecting system
	Vascular	Main renal artery or vein injury with contained hemorrhage
V	Laceration	Completely shattered kidney
	Vascular	Avulsion of renal hilum which devascularizes kidney

Figure 1. Renal trauma classification by the American Association for the Surgery of Trauma (AAST).[42]
*Advance one grade for bilateral injuries up to grade III.

pelvis, and segmental arterial/venous injuries. Grade 5 in this stratification is limited to major vascular injuries.

Injury severity distribution according to the AAST classification (based on two national trauma registry studies[5,17] and a systematic review[31]): grade I, 22–28%; grade II, 28–30%; grade III, 20–26%; grade IV, 15–19%; grade V, 6–7%.

Initial evaluation: patient history, physical examination and laboratory tests

Initial assessment of every trauma patient that arrives in the emergency department includes a primary survey to evaluate airway, breathing and circulation, and taking vital signs, that is, heart rate, blood pressure, and blood oxygen saturation.

Patient history

Patient history and details of the event that caused the injury may not be available in a hemodynamically unstable patient, but when the patient is stable these data are very relevant for making the right treatment decisions. Understanding the injury mechanism and the forces involved is important because in cases of high deceleration or acceleration forces there is a high risk of renal injury, and further imaging should be done.[38] The patient's medical history is relevant as well. Pre-existing kidney abnormalities put the patient at specific risk, even from low-velocity impacts, and therefore further imaging studies should be generously indicated. The management of abnormal kidneys unmasked by trauma is largely dependent on the type of pathology.[39,40] In cases of a solitary kidney or a solitary functioning kidney, a nephrectomy should be avoided unless it is crucial.

Physical examination

Physical examination helps to determine the location, extent and the severity of the injury. Blunt trauma to the flank, back, lower thorax and upper abdomen may harm the kidney. The physician should look for penetrating entry and exit wounds, abdominal peritoneal signs (e.g. guarding sign, rebound tenderness), and signs that may indicate renal trauma, such as visible hematuria, flank/upper abdomen hematoma, palpable mass, ecchymosis or abrasions, and rib fractures.[48–50]

Laboratory tests

Urine analysis, hematocrit and creatinine levels are necessary tests in order to diagnose microscopic hematuria, current blood loss status and baseline renal function,[51] respectively. When active bleeding is suspected, blood type cross and match is mandatory. Additional laboratory evaluation should include complete blood count, blood gases and complete chemistry, including glucose, electrolytes, liver function tests, amylase and lipase to evaluate for other possible abdominal organ injury.

Hematuria, visible or nonvisible, is a very common sign of renal trauma. Nonvisible, also known as microscopic hematuria, is defined as three or more red blood cells (RBCs)/high power field (HPF) for adults[52] and over 50 RBCs/HPF for pediatric patients.[53] Visible hematuria is only present in 35–77% of renal trauma cases.[10,45,54] Almost half of the patients with grade II renal trauma and 30% of the patients with grade IV renal trauma have no hematuria at presentation.[45] Visible hematuria is even less common in penetrating renal injuries.[30] Therefore, there is no absolute relationship between the type or degree of hematuria and the type and severity of the injured kidney.

Imaging

Computed tomography

Intravenous contrast-medium enhanced computed tomography (CT) is currently the gold standard imaging method for hemodynamically stable patients with blunt and penetrating renal trauma.[1,48,55,56] It is widely available and it can quickly and accurately locate renal and other organ injuries by the anatomic and functional information that is essential for accurate staging.[57] Concern regarding the toxicity of the contrast medium has not been confirmed, since low rates of contrast-induced nephropathy are seen in trauma patients.[58] CT for renal trauma should include four phases: precontrast, postcontrast arterial (35 s post intravenous injection), postcontrast nephrogenic/portal venous (75 s post intravenous injection) and delayed (5–10 min post intravenous injection).[22,57] The precontrast phase can identify renal calculi, which affect management,[39,40] active bleeding or intraparenchymal hematoma.[57] Postcontrast phases identify parenchymal and vascular damage, including the presence of active extravasation of contrast, other solid organ damage (e.g. liver and pancreas) and physiological variants that may affect management.[57] The delayed phase can visualize the collecting system and possible ureteric injury.[22] If the delayed phase cannot be performed during initial assessment due to urgent priorities, it should be completed whenever possible.

Intravenous pyelography

Intravenous pyelography (IVP) has been replaced by contrast-enhanced CT, except as an intraoperative tool to confirm the presence of a contralateral functioning kidney in a hemodynamically unstable patient, who could not complete preoperative CT. The use of intraoperative IVP includes a one-shot bolus injection of contrast media (2 mg/kg), followed by a single plain film taken after 10 min.[59]

Ultrasound

Ultrasound (US) is used to define free fluid in the setting of trauma, but it is inferior to CT in its resolution and the ability to accurately describe renal injury.[60,61] In well trained and experienced hands, renal lacerations and hematomas can be reliably identified and delineated.[62] However, US examination is unable to distinguish fresh blood from extravasated urine, and cannot identify vascular pedicle injuries and segmental infarct.[60] US can be used for follow up of hydronephrosis, renal laceration managed nonoperatively and postoperative fluid collection.[48] The absence of radiation, which is one of the main advantages of US, is very relevant for pediatric patients.

Indication for initial imaging

The goal of initial imaging is to grade the renal injury, demonstrate contralateral kidney and preexisting renal abnormalities, and identify injuries to other organs. The decision to obtain an initial image is based on clinical aspects and the mechanism of injury. According to the European Association of Urology (EAU)[63] and the American Urological Association (AUA) guidelines,[55] CT should be performed in all hemodynamically stable blunt trauma patients with either gross hematuria or patients presenting with microscopic hematuria and hypotension (systolic blood pressure <90 mmHg) at presentation. It should be clear that hemodynamic instability does not allow the diagnostic use of a CT. Moreover, CT should be performed when the mechanism of injury or the physical examination findings are suggestive of renal injury (i.e. rapid deceleration, a rib fracture, substantial flank ecchymosis, and every penetrating injury of the abdomen, flank or lower chest).

Indication for reimaging

The goal of reimaging is to diagnose possible complications and to evaluate clinical deterioration. Current guidelines recommend reimaging for patients with high-grade injuries after 2–4 days.[48,55,63] Reimaging is also indicated for patients with clinical signs of complications, such as fever, worsening flank pain, ongoing blood loss and abdominal distension.[48,55,63]

Renal trauma management

The priorities of renal trauma management are (on descending order) avoiding mortality by bleeding control, nephron sparing and avoiding complications. In the past, the common practice to achieve these goals was to operate. Clinicians assumed that the best way to control bleeding is by surgery and the highest chance to avoid nephrectomy is by surgery where you can reconstruct vascular, UPJ or parenchymal injury as needed. In the last decades, real trauma management has evolved with a constant transition toward a nonoperative approach with nonoperative management (NOM) when needed, due to accumulative knowledge of the safety and better outcome of this approach.[2–5,31] This approach includes both pediatric and adult populations.

Current indications for renal intervention

Absolute indications. According to current guidelines,[55,63] absolute indications for renal intervention are hemodynamic instability and unresponsiveness to aggressive resuscitation due to renal hemorrhage, grade 5 vascular injury and an expanding or pulsatile perirenal hematoma found during laparotomy performed for associated injuries.

Relative indications. The renal trauma subcommittee summarized relative indications for renal exploration.[48] They include a large laceration of the renal pelvis, avulsion of the UPJ, coexisting bowel or pancreatic injuries, persistent urinary leakage, and postinjury urinoma or perinephric abscess with failed percutaneous or endoscopic management. Additional indications are abnormal intraoperative one-shot IVP, devitalized parenchymal segment with associated urine leak, complete renal artery thrombosis of both kidneys or of a solitary kidney, and renal vascular injuries after failed angiographic management.

Nonoperative management

NOM includes observation with supportive care, bed rest with vital signs and laboratory test monitoring and reimaging when there is any deterioration), with the use of minimally invasive procedures (angioembolization or ureteral stenting) if indicated.

In two large-scale cohorts, renal trauma was managed nonoperatively in 84–95% of cases, with 2.7–5.4% of NOM failure.[5,31] The effectiveness of NOM is supported by a systematic review and meta-analysis[64] and by a smaller prospective study,[11] and was found to be effective in treating complications of primary treatment as well.[15]

Nonoperative management for patients with blunt renal trauma. Grade I–II Patients with grade I and II renal trauma should be treated with NOM. In several studies, there was no need for a nephrectomy in any patient and rare indications for renal exploration.[45,47,65]

Grade III In two studies with grade III blunt renal trauma patients the reconstruction rate was 73% (87/119) and 11% (9/82) and the nephrectomy rate was 3.3% (4/119) and 4.8% (4/82), respectively.[45,65] The nephrectomy rate was very low (1.8%) in another study (3/171).[66] Aragona and colleagues found that among 21 patients with grade III blunt renal trauma the nephrectomy rate was 9% but when it was divided into two periods (2001–5, 2006–10) it was found that during the second period there were no nephrectomies. This is attributed to the growing use of angioembolization.[54] Angioembolization has a success rate of 89% for the first time and 82% when repeated,[67] and its effectiveness has been proven in treating patients with even higher grade renal trauma (IV/V).[9,14,23,24,67] Therefore, patients with grade III renal trauma can be treated with NOM, by active monitoring and use of angioembolization if indicated.

Grade IV–V Most grade IV blunt renal injuries are treated nonoperatively, with a low incidence of nephrectomy.[7,68] As mentioned before, there is a trend toward NOM for patients with grade IV blunt trauma with better outcome,[54] which is attributed to the use of angioembolization. Lanchon and colleagues presented their first-line NOM protocol in 149 patients with grade IV or V renal blunt trauma. NOM was successful in 82% of the patients, with higher success in patients with grade IV (89% *versus* 52%) and the predictors for NOM failure were higher grade and hemodynamic instability. Eighteen percent underwent angioembolization, 17% underwent ureteral stent insertion, and 18% required delayed surgery.[9] McGuire and colleagues used a similar protocol in 117 patients with grade III–V renal trauma. A total of 83% were treated with NOM and 9.3% (9/97) needed intervention: angioembolization in eight cases and only one case of nephrectomy. Predictors for intervention were grade V [relative risk (RR) 4.4] and use of platelets (RR 8.9). Van der Wilden and colleagues found that 77% (154/201) of patients with grade IV or V blunt renal trauma had successful NOM with no loss of kidney units. Age over 55 years and MVAs were the only two predictors for NOM failure.[16] Angioembolization was successful in all nine patients with grade V blunt renal trauma in another study.[24]

According to these data, patients with grade IV–V blunt renal trauma who are hemodynamically stable should have the opportunity for NOM with active surveillance.[55]

Nonoperative management for patients with penetrating renal trauma. In the past, penetrating renal trauma was an absolute indication for renal exploration. Currently there is increasing evidence that supports NOM for hemodynamically stable patients with penetrating renal trauma.[2,4,18,19,21] Penetrating renal trauma has a higher nephrectomy rate per grade injury,[29] a higher rate of multiorgan injuries[30] and a higher failure rate of angioembolization compared with blunt renal trauma.[23] Nevertheless, most penetrating injuries can be treated nonoperatively.[69] Moolman and colleagues found that 63% (47/64) were treated with NOM, none of them needed surgery.[10]

Operative management

Despite the obvious benefits of NOM, there are several situations in which surgery is the best option. Bjurlin and colleagues found that among 19,572 patients with renal trauma, 16.6% were managed surgically.[5] Most clinicians would operate in hemodynamically unstable patients who do not respond to resuscitation.[59] The most common approach is transperitoneal,[70] with isolation of the renal artery and renal vein before renal exploration as a safety maneuver.[71] This approach was found to reduce the nephrectomy rate from 56% to 18%.[72] Vessel isolation was well described by Santucci and McAninch.[29] Optimal control of the renal vessels enables the surgeon to avoid unnecessary nephrectomy by a thorough evaluation of the retroperitoneal area, although Gonzalez and colleagues found that vascular control of the renal hilum before opening Gerota's fascia has no impact on the nephrectomy rate, transfusion requirements or blood loss.[73] A stable hematoma should not be opened while a central or expanding hematoma, which indicates injuries of major vessels (renal vessels, aorta, vena cava), should be surgically explored.[48]

Renal salvage by renorrhaphy or partial nephrectomy requires maximal exposure of the kidney, debridement of nonviable tissue, control of bleeding by sutures, watertight closure of the collecting system and closure of parenchymal injuries. The omental flap of perirenal fat can be used for coverage of large defects.[48] In all cases, drainage of the ipsilateral retroperitoneum is recommended for at least 48 h.[29] In cases of suspected pancreatic injury, a second, pancreatic drainage should be placed to prevent abscess or fistula formation.[74]

Complications

Early complications include bleeding, infection, perinephric abscess, sepsis, urinary fistula, hypertension, urinary extravasation and urinoma. Delayed complications include bleeding, hydronephrosis, calculus formation, chronic pyelonephritis, hypertension, arteriovenous fistula, hydronephrosis and pseudo aneurysms. Most of the complications can be treated nonoperatively, percutaneously and endourologically. Renal trauma is a rare cause of hypertension and is estimated to be less than 5%.[75] Persistent urinary extravasation from an otherwise viable kidney after blunt trauma often responds to stent placement or percutaneous drainage as necessary.[76]

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest statement

The authors declare that there is no conflict of interest.

ORCID iD

Noam D. Kitrey https://orcid.org/0000-0001-5587-1485

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