AUA **Update Series** 2020

Lesson 28 Volume 39

Renal Trauma*

Learning Objective: At the conclusion of this continuing medical education activity, the participant will be able to describe the epidemiology, mechanism, modalities and guidelines to manage renal trauma.

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Disclosures: Nothing to disclose

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Release date: September 2020

Expiration date: September 2023

Key Words: wounds and injuries; renal; kidney; embolization, therapeutic

INTRODUCTION

Trauma is a major cause of death and disability. Genitourinary trauma accounts for 10%–20% of all traumatic injuries.[1] Kidney injury, which is the most common genitourinary organ injury, occurs in 10% of all abdominal injuries, has a male predominance and more frequently occurs in young individuals.[2-5] Renal trauma is graded from I–V based on injury severity, with grade V representing the most severe injury, and is classified as blunt or penetrating. Blunt injuries are most commonly due to high energy deceleration collisions in the setting of motor vehicle accidents, falls and contact sports.[5] In urban settings, undeveloped countries and the military penetrating injuries caused by knife and gunshot wounds are more common and account for at least 20% of cases.[6]

Staging of renal trauma with computerized tomography is ideal when possible and can guide management. CT with immediate and delayed images should be done when there is suspicion of renal injury. Patients with renal parenchymal injury and urinary extravasation may initially be observed. Urinary drainage should be done in the presence of complications such as enlarging urinoma, fever, increasing pain, ileus, fistula or infection. Diagnostic angiography and/or renal artery embolization is the most common non-operative management strategy, and may obviate open surgery and minimize the need for nephrectomy. However, renal trauma can be life-threatening owing to major bleeding and/or association with injury to other organs such as the liver, spleen or intestine. While most renal trauma can be managed conservatively with close monitoring, particularly in patients who are hemodynamically stable,[7] in cases where intervention is needed center expertise and injury severity will help determine therapy. Patients with high grade renal trauma should be monitored long term for hypertension.

CLASSIFICATION OF RENAL INJURY

The American Association for the Surgery of Trauma Organ Injury Scale (see Appendix), originally described in 1989, has historically and widely been used to classify renal injury.[8] The most recent revision was published in 2018.[9] The scale consists of 5 grades, which are arranged in order of increasing severity according to the depth of injury, renal vascularity and collecting system involvement. The AAST classification has been shown to predict outcomes associated with each grade of injury and correlates well with CT findings.[10-12] It is a strong predictor of the need for operative management and correlates with morbidity and mortality.[13] According to the National Trauma Data Bank®, the national distribution of renal injuries is grade 1, 28%; grade 2, 30%; grade 3, 20%; grade 4, 15%; and grade 5, 17%.[14]

The 2018 AAST Organ Injury Scale for renal trauma incorporates CT findings and vascular injuries (ie pseudoaneurysm, arteriovenous fistula), which were not completely addressed in the original scale.[9] The new grading system specifically includes segmental renal artery or vein injury, which is not in the original AAST grading system. In addition, grade V injuries now require active bleeding in a devascularized kidney. Finally, the new classification scheme advances bilateral injuries by 1 grade, up to grade III. A study evaluating the predictive ability of the new grading system evaluated the system in 322 patients with renal trauma and demonstrated that 33% of grade III injuries were upgraded to grade IV and more than 50% of grade V injuries were downgraded.[10] In addition, in this study the odds of intervention were increased in the presence of grade IV and V injuries. Importantly the new grading system is as good as the old grading system at predicting interventions after renal trauma but does not have better performance or predictive ability.

MECHANISMS OF INJURY

Blunt trauma. The kidney is the most frequently injured genitourinary organ and accounts for 1%–5% of all trauma cases.[3,4,15] The most common mechanisms are blunt injuries, which occur from high energy deceleration collisions from motor vehicle accidents, falls, assault and contact sports. A recent study evaluated the prevalence of mechanisms for blunt renal injuries and motor vehicle accidents were most common, accounting for 61% of cases, followed by falls (11%), pedestrian injuries (9%) and sports injuries (7%).[16]

Given the high retroperitoneal position of the kidneys and their cushioning by perirenal fat, abdominal viscera and robust back musculature, major high deceleration forces are necessary to inflict injury. This explains why many times when there is renal injury, concurrent injuries to the surrounding abdominal viscera are noted. The most common form of renal damage is parenchymal contusions or lacerations. It is estimated that 5% of blunt renal trauma results in major renal vascular injury such as avulsion or thrombosis.[17] Moderate forces are required for thrombosis, while severe forces are needed for hilar avulsion. Shearing of the intimal lining of the renal vasculature from deceleration or compression from the surrounding viscera, muscles and skeletal system results in activation of a clotting cascade, which can lead to thrombosis.[18] Injuries to the renal parenchyma classically present with hematuria. However, renal pedicle injuries can easily be missed given that 25%–50% of these patients do not present with hematuria.[12] Appropriate imaging is critical.

The pediatric patient is unique when considering renal trauma. In children traumatic injury is the leading cause of mortality, and blunt trauma is the most common mechanism.[19] Children are at higher risk for traumatic renal injuries due to less protection from perirenal fat, the large size of pediatric kidneys and the presence of less abdominal musculature, which is largely protective, and an immature rib cage that is not completely ossified. Renal injuries in children typically occur from deceleration trauma incurred during contact sports and sports related accidents such as falls sustained when skiing or biking. Most high grade renal injuries occur in the setting of motor vehicle accidents or falls from a high altitude.[20]

As in adults, the primary objective after a pediatric patient has sustained renal injury is preservation of renal function. There are no well established guidelines in the pediatric literature on management, imaging or follow-up, although strategies

ABBREVIATIONS: AAST (American Association for the Surgery of Trauma), AE (angioembolization), AUA (American Urological Association), CT (computerized tomography) have been proposed.[19] Unlike adults, children have greater physiological reserve and may not demonstrate hypotension or other signs, although they may have significant renal injury. As in adults, most blunt renal trauma is managed non-operatively, and a renal preservation rate of up to 99% has been reported.[3,21,22]

A meta-analysis of grade IV renal injuries in pediatric patients showed that 72% were managed non-operatively. Of the 11% of patients requiring surgical intervention 46% underwent partial nephrectomy and 27% underwent nephrectomy.[23] A different study examined blunt renal trauma in pediatric patients for a period of 20 years and showed that only 6.3% of patients required surgical intervention for grade IV and V renal injuries.[24] Of patients with grade IV and V renal injuries only 16.3% required surgical intervention. Collectively these findings suggest that non-operative management should always be considered when possible for grade IV renal injuries in pediatric patients. Intervention should be done immediately in cases of hemodynamic instability, and intervention should be considered when there is continued hemorrhage, urinary extravasation and/or infection.

Penetrating trauma. Penetrating renal injuries, classically knife injuries and gunshot wounds, account for roughly 16% of renal trauma.[25] Compared to blunt trauma, these injuries are less prevalent but when they do occur they are often more severe and involve multiple organs given the direct tissue damage and blast effect from gunshot wounds. Renal trauma in general is associated with concurrent injuries in up to 86% of cases.[26] In these injuries it is critical to know about the weapon used, type of weapon and, if a gunshot wound, type of ammunition. Penetrating trauma is classified according to the velocity of the projectile and is classified as high, medium or low velocity. This information can be key in assessment of trauma cases involving these injuries. For example a higher bullet velocity results in greater tissue damage due to formation of a temporary cavity that immediately collapses, creating shear forces and extensive destruction that is wider than the initial projectile tract.[27] In addition, an expanding bullet by design mushrooms to double its size as it penetrates tissue planes, resulting in greater tissue damage. Finally, ballistic properties of bullets result in an unpredictable trajectory and tissue damage.[28] Given these factors, it is recommended that any patient with a gunshot wound to the chest or upper abdomen be evaluated for concomitant renal trauma.[29]

It is also important to pay particular attention to the location of penetration, which can be predictive of injury severity. Penetrating injuries anterior to the anterior axillary line more often result in higher grade injuries given close proximity of the renal pedicle, hilum and renal pelvis.[30] Concurrent intra-abdominal organ injuries are more common with anterior lesions as well. Stab wounds in the flank, posterior to the anterior axillary line, generally result in lower grade, more peripheral parenchymal injuries.

Fortunately in children penetrating renal injury is a rare event, accounting for less than 10% of all renal injuries.[2] The literature guiding the management of penetrating renal injuries in the pediatric population has been limited to small retrospective series. Studies indicate that penetrating trauma typically occurs predominantly in very young (ages 0–1 year) and older children (ages 15–18 years).[31] Penetrating renal trauma is also more prevalent in black and Hispanic children.[2] As in adults, non-operative management when possible should be adopted in children with penetrating renal injury, although a higher proportion of children with high grade penetrating injuries will require intervention.[32]

EVALUATION

Initial evaluation. The trauma patient arriving in the emergency department should undergo the American College of Surgeons Acute Life Support primary survey, which includes the ABCDE algorithm, consisting of assessments of the airway, breathing, circulation (external bleeding control), disability (neurological status) and exposure (undress)/environment (temperature control). Physical examination often follows while resuscitation is initiated, and monitoring devices are placed for essential hemodynamic assessments. Physical examination of the urethra, perineum and rectum should be performed, which helps to determine location, extent and severity of the injury. On examination penetrating wounds should be inspected for entry and exit. Blunt trauma to the flank, lower back, thorax and upper abdomen can cause kidney injury. The flank should also be inspected for ecchymosis, abrasions, hematoma, palpable mass and flank pain as these are all indicative of renal trauma.[18, 31] The patient should also be examined for rib fractures, which may indicate renal trauma. Microscopic or gross hematuria should be evaluated via Foley catheter placement or urine specimen if the patient is able to void.

Laboratory testing. Urinalysis, hemoglobin, hematocrit and creatinine levels are routinely obtained. Urinalysis can evaluate hematuria, while hemoglobin and hematocrit assess blood loss status and creatinine levels establish baseline renal function. Injuries to other abdominal organs can be evaluated with additional laboratory tests including blood chemistry, hepatic panels, amylase, lipase and blood gases. Microscopic hematuria is defined as 3 or more red blood cells per high power field in adults and over 50 red blood cells per high power field in children. Of patients with grade II renal trauma 50% will have no hematuria at presentation. Of those with grade IV trauma 30% will have no hematuria.

Indications for imaging. **Per AUA guidelines, clinicians should perform diagnostic imaging with intravenous contrast enhanced CT in stable patients with blunt trauma with gross hematuria and systolic blood pressure <90 mm Hg, and in patients with trauma with mechanism of injury or physical examination findings concerning for renal injury.[33]** Physical examination findings such as rapid deceleration, substantial impact to flank, flank ecchymosis and penetrating injury of the abdomen, flank or lower chest all indicate the high possibility of renal trauma. In hemodynamically stable patients intravenous contrast enhanced CT is the gold standard evaluation.[34-36]

Hypotension and hematuria are not good screening criteria for imaging and workup, and their use may miss injuries given that children might not display typical signs of shock. Moreover, hematuria in children may be associated with a congenital anomaly or a vascular neoplasm, and up to 20% of those undergoing CT of the abdomen for trauma will have incidentally found renal anomalies. Generally imaging is recommended for children with microscopic or gross hematuria following trauma. **In addition, a child with a significant concomitant injury or a mechanism of injury such as a rapid acceleration and deceleration, high velocity impact, fall from >15 feet or a direct blow to the abdomen or flank should undergo imaging irrespective of**

the presence of hematuria.[37] All clinically stable children with penetrating abdominal or pelvic trauma should undergo radiographic assessment.[19] CT should be the gold standard imaging modality. Ultrasound, although associated with less radiation exposure, can miss parenchymal and collecting system injuries, and CT is superior.[38] However, ultrasound is the preferred modality for follow-up serial imaging.

Imaging modalities. Computerized Tomography: **Clinicians should perform intravenous contrast enhanced abdominal/pelvic CT with immediate and delayed images when there is suspicion of renal injury.**[33] Typically patients with trauma who are undergoing CT have had laboratory evaluations confirming normal creatinine. However, a study of 1099 patients with renal trauma demonstrated that those younger than 61 years old who are normotensive and non-diabetic are largely unlikely to have impaired renal function, and in the setting of trauma it is safe to proceed with contrast enhanced imaging prior to screening of renal function.[39] Other indications for delayed imaging include low density fluid tracking around the kidney and down the ureter, which, if present on initial contrast enhanced CT, may indicate a ureteropelvic junction or ureteral injury. Without delayed images these injuries may be missed, with potential detrimental consequences.[40] Ureteropelvic junction ruptures are often indicated by extravasation of contrast material, while avulsion is indicated by absence of contrast in the distal ureter on delayed images. Ureteropelvic junction injuries were historically missed in 50% of cases, although routine evaluation of trauma cases with delayed image CT has increased the initial detection rate to almost 90%.

In many scenarios the delayed phase cannot be done during the initial imaging assessment given urgency and hemodynamic instability. In these cases this imaging should be completed when possible. If there are no signs of kidney injury, delayed views are often omitted given the low chance of ureteral injury.

Radiological findings that indicate renal injury include arterial medial extravasation of contrast material, which indicates a severe arterial injury. Venous injuries are denoted by a medial hematoma without arterial extravasation. Arterial injury or thrombosis is indicated by differential contrast uptake and excretion. A main renal artery injury is suggested by a cortical rim sign. Other important radiological findings include degree of parenchymal laceration and involvement of the collecting system, quantification of devitalized tissue, and the size and location of a perinephric hematoma or fluid collection.[5] **Clinicians should perform follow-up CT for renal trauma in cases with deep lacerations (AAST grade IV–V) or clinical signs of complications (fever, ongoing hemorrhage, abdominal distention, increasing flank pain).**[33]

It is recommended that repeat imaging be obtained anywhere from 48–96 hours following the initial imaging study, and earlier if needed. However, despite this recommendation, there is evidence that repeat imaging can be tailored based on an individual's specific injury. For instance a recent analysis of repeat imaging in patients with grade IV or V renal trauma at 3 level 1 trauma centers over 19 years (1999–2017) demonstrated that 1 of 8 asymptomatic patients would need to undergo repeat imaging to identify 1 who needed surgical intervention.[41] Given that the primary goal of repeat imaging is to evaluate for complications and clinical deterioration, it may be more worthwhile to obtain repeat imaging in patients who have a history of collecting system injury. Stable patients with grade I–III injuries generally do not require repeat imaging.

Given that increased radiation exposure in children raises the risk of carcinogenesis,[42] care should be taken to use the minimum necessary dosage to achieve adequate assessment of the child with renal trauma. While the initial CT necessary in cases of renal trauma, repeat CT may be avoided in pediatric patients.[43] A study evaluating repeat CT in 145 children at 2 level 1 trauma centers revealed that 1 of 5 underwent repeat imaging less than 48 hours after the initial CT.[44] In addition, delayed imaging on the initial CT predicted the likelihood of undergoing a second CT. This study suggested that ultrasound may be a good replacement for repeat CT.

Angiography. Diagnostic angiography and/or renal artery embolization may obviate surgery and minimize the need for nephrectomy. However, there is evidence of overuse in less severe injuries and this procedure is not without risk.[45] A recent study of a statewide trauma database indicated high rates of diagnostic angiography and renal artery embolization in low grade renal trauma, specifically up to 5.7% in isolated grade I renal injuries.[46] Other studies demonstrate high use in low grade renal trauma, which is often a consequence of concurrent solid abdominal organ injuries given the wide use of angiography for other solid organs such as the liver and spleen.[6,47] Data from the National Trauma Data Bank show evidence of a lower rate of use (2%) with increasing use associated with rising AAST grade.[47] Of cases managed by diagnostic angiography 37% were in the low grade category, which mostly contained individuals with concomitant solid organ injuries. There is no gold standard on the use of diagnostic angiography.

Intravenous pyelography. Intravenous pyelography has been replaced by high resolution cross-sectional imaging and should not be done unless CT is unavailable or a patient is too unstable and has not undergone preoperative imaging with concern for renal injury.[48] A bolus intravenous injection of 2 ml/kg radiographic contrast material is administered and a single plain film is taken after 10 minutes. This imaging is critical in identifying a contralateral kidney or ureteral injury. For example if there is a solitary kidney, concerted efforts should be made to salvage the injured kidney.

MANAGEMENT

Non-operative. **Clinicians should use non-invasive management strategies in hemodynamically stable patients with renal injury.** The objectives of managing renal trauma include bleeding control, nephron sparing when possible and prevention of complications. In the past it was believed that these goals were best achieved by operating in patients with renal trauma. Over the last 2 decades a transition to non-operative management when possible has been prioritized in adults and children given the improved outcomes with this approach along with nephron sparing and the relative safety.[49] Non-operative management is inclusive of supportive care, bed rest, vital sign measurement, serial hemoglobin/hematocrit measurement and reimaging when needed, as well as use of minimally invasive procedures when and if indicated.

Nephrectomy is not without complications, and is associated with a higher risk of renal insufficiency and cardiovascular disease.[13] Therefore, non-operative management is a mainstay for grades I–IV renal injury, and surveys of practice patterns indicate that most practitioners see value in renal preservation.[50] Another impetus for non-operative management is that studies have shown that patients who underwent renal exploration for low to moderate grade trauma have a twofold increased risk of complications.

The usefulness of non-operative management in low grade renal trauma is quite clear. A systematic review and meta-analysis evaluated non-operative management for renal trauma and compared it to operative management for the outcomes of mortality, morbidity and length of hospital stay.[51] A total of 20 studies with 13,824 patients (2998 with blunt injury and 10,826 with penetrating injury) were evaluated. Compared to operative management, non-operative management had lower rates of morbidity (53% vs 2%) and mortality (17% vs 8.3%). Considering only high grade trauma, mortality was lower in patients undergoing non-operative management for both blunt (4.1% vs 8.1%) and penetrating (9.1% vs 18.1%) trauma. The authors of this study concluded that non-operative management should be the gold standard for low and high grade blunt and penetrating renal trauma.

In the past penetrating renal trauma was an absolute criterion for renal exploration. However, increasing evidence and the literature support non-operative management for patients sustaining penetrating renal trauma who are hemodynamically stable.[52] It is noteworthy that compared to blunt trauma, penetrating trauma has a higher nephrectomy rate, an increased rate of injury to multiple organs and a higher angioembolization rate.[47,53] A study evaluating renal trauma assessed 1842 patients with penetrating renal trauma in the American College of Surgeons Trauma Quality Improvement Program database.[54] Lower rates of in hospital complications and shorter intensive care unit stays were noted in the non-operative management group. Non-operative management failed in 26 patients (8%). Predictors of failure were concurrent abdominal organ injury and higher AAST grade.

MiGUTS (Multi-institutional Genitourinary Trauma Study), which considered non-operative management after high grade renal trauma, assessed the association of radiological findings with interventions in 326 patients.[55] In this series radiological findings including the presence of vascular contrast extravasation and hematoma rim distance were predictive of interventions.

Operative. **The surgical team must perform immediate intervention (surgery or angioembolization in select situations) in hemodynamically unstable patients with no or transient response to resuscitation.[33]** While there are clear benefits of non-operative management approaches, in some scenarios operative management is the best option. Absolute criteria for renal exploration include life-threatening hemorrhage with hemodynamic instability and renal pedicle avulsion, as well as expanding, pulsatile or uncontained retroperitoneal hematoma.[56] Relative criteria for operative management of renal trauma include incomplete radiographic staging with concurrent traumatic injuries that require repair/exploration, extensive devitalized renal parenchyma, vascular injury and urinary extravasation. A nomogram using data from MiGUTS demonstrated that hematoma size, penetrating trauma mechanism, vascular contrast extravasation, perirenal hematoma extension, multiorgan injuries and shock were predictive of the need for bleeding interventions following high grade renal trauma.[55] A study of the National Trauma Data Bank evaluating prediction of when non-operative management fails indicated that penetrating injuries, multiorgan injuries and highest renal injury grade are associated with failure, and may be helpful in clinical settings to identify those patients at highest risk for failure and the need for operative management.[49]

The approach used for nephrectomy or renorrhaphy in a trauma setting is often transperitoneal, with the initial steps including isolation of the renal hilum before renal exploration.[57] This approach has been shown to reduce nephrectomy rates from 56% to 18%.[58] A stable hematoma should not be explored, whereas a central or expanding hematoma should be explored as it indicates injury to major vessels. Renorrhaphy or partial nephrectomy is optimized by maximal exposure of the kidney, control of bleeding, and closure of collecting system and any parenchymal injuries. Large defects may be covered by an omental flap.[34]

Embolization. Angioembolization has success rates of 89% for initial angioembolization and 82% for repeat angioembolization.[59] AE traditionally has high success rates for low grade trauma and has come to the forefront in the management of high grade trauma as well. However, despite its increasing use in patients with high grade trauma, there are high failure rates necessitating secondary interventions.

Clinical criteria that may predict the need for renal AE are mechanism of injury, hemodynamic stability, AAST renal injury grade, multiorgan injury, active arterial bleeding and perirenal hematoma size.[60] A study evaluating clinicians' use of AE demonstrated that evidence of active arterial bleeding or arteriovenous fistula/pseudoaneurysm on CT is an indication for AE.[61] Vascular contrast extravasation has been shown to be a major predictor of angioembolization, and most patients with vascular contrast extravasation on initial imaging will require angioembolization. An algorithm for management of renal trauma is provided in the figure.

COMPLICATIONS

Extravasation/urinoma. **Clinicians may initially observe patients with renal parenchymal injury and urinary extravasation.[33] Urinary drainage should be performed in the presence of complications such as enlarging urinoma, fever, increasing pain, ileus, fistula and infection. Drainage should be achieved via ureteral stent and may be augmented by percutaneous urinoma drain, percutaneous nephrostomy or both.[33]**

Diagnosis and management of urinary extravasation are critical in renal trauma and comprise criteria for intervention in certain instances. Many cases of minor urinary extravasation do not require intervention. A recent meta-analysis of 24 studies demonstrated the prevalence of urinary extravasation was 29% in grade III–V injuries combined, of which 74% occurred in grade IV injuries, and 51% in grade IV and V injuries combined.[62] In 15 studies including data on ureteral stents for urinary extravasation 29% of patients with urinary extravasation underwent ureteral stent placement. Although ureteral stenting is recommended in cases of persistent or worsening urinary extravasation, it is unclear in these studies whether stents were placed due to complications or were placed early and were unnecessary. Importantly spontaneous healing is possible in many cases of renal trauma associated with urinary extravasation.[37]

Arteriovenous fistula. Post-traumatic arteriovenous and arteriourinary fistulas are rare, with an estimated incidence of 0%–7%, and can occur after blunt and penetrating trauma.[46] Most often they occur days or weeks after injury,[63] although in

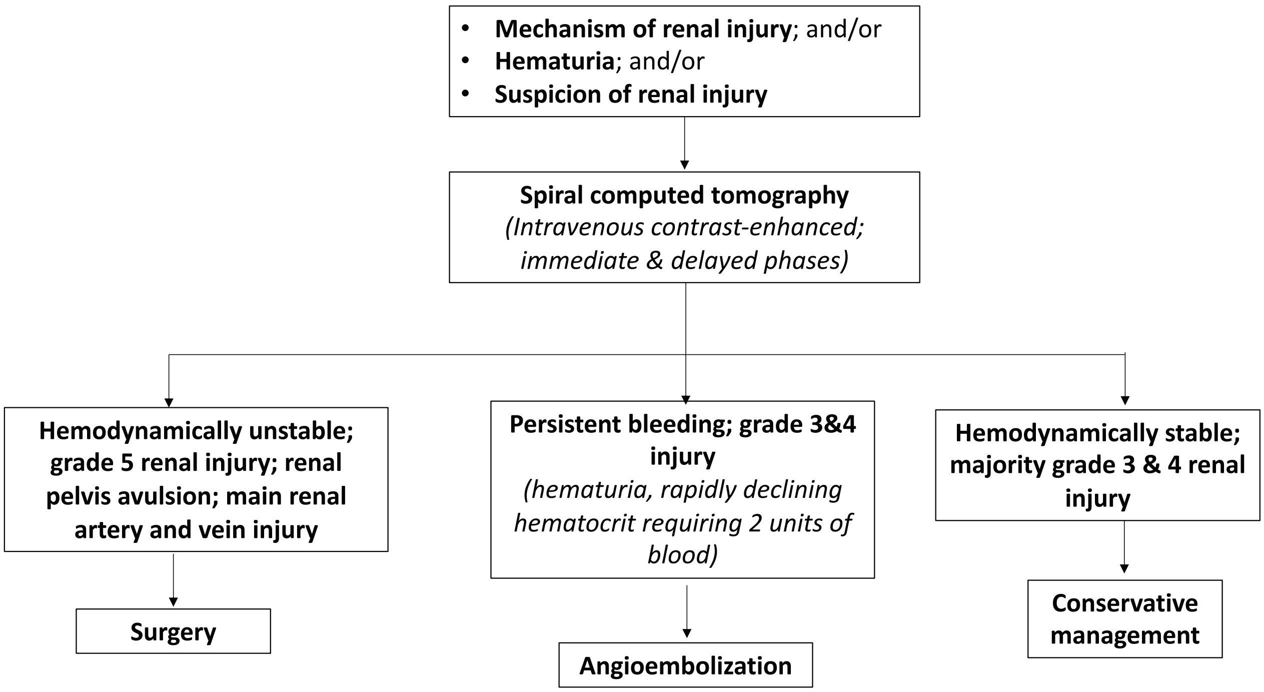

Figure. Renal trauma management algorithm.[76]

rare instances they have been reported to occur several years after trauma.[64, 65] Clinical manifestations include hematuria, hemodynamic instability secondary to bleeding and cardiovascular complications. Arteriovenous fistulas can be diagnosed with contrast enhanced CT as well as angiography. Magnetic resonance angiography may be slightly more sensitive for diagnosis.[47] Angiography with superselective AE is the standard treatment and is generally safe and effective.[48] Some cases may heal spontaneously without treatment.[66]

Pseudoaneurysm. Pseudoaneurysms are rare and generally occur after penetrating trauma, although they can also occur after blunt trauma. A study of penetrating trauma demonstrated an incidence of 7.9%.[67] Patients with renal artery pseudoaneurysm may present with flank pain, hematuria, abdominal bruit or hypertension. In some instances patients may be asymptomatic with rupture before diagnosis or treatment. Contrast enhanced CT is most often the study of choice but Doppler ultrasound may identify pseudoaneurysm as an anechoic lesion with characteristic "to and fro" swirling.[49] Angiography with embolization is the gold standard for definitive diagnosis and treatment.

Secondary hemorrhage. Secondary hemorrhages often occur 2–3 weeks after penetrating injury with deep cortical lacerations and can be life-threatening.[50] A majority of cases of secondary hemorrhage are caused by arteriovenous or arteriourinary fistula and/or pseudoaneurysms. Others may be due to injured segmental arteries. In cases of secondary hemorrhage emergent angiography with selective angioembolization is the treatment of choice.

Hypertension. Renal trauma may increase subsequent development of hypertension due to renal injury not only from the trauma, but also from treatments for trauma such as angioembolization resulting in renovascular injury, disturbance to the renin-angiotensin system and external compression.[68, 69] Renovascular hypertension after trauma may develop through Page kidney, which is a phenomenon caused by external compression of the parenchyma. In the case of renal trauma this is caused by a perinephric hematoma, which subsequently results in decreased renal blood flow. Reduced renal blood flow then can result in hypersecretion of renin, leading to hypertension.

Hypertension following renal trauma is estimated to occur in 0.6%–33% of patients. A recent study examined hypertension development amongst 163 patients who presented with renal trauma at a level 1 trauma center.[70] In this study hypertension developed in 14% of patients, with a median onset of 8 months. Patients were generally older with longer follow-up and high grade renal trauma. CT findings associated with development of hypertension were mid pole medial laceration and medial blood. Despite this and other studies on hypertension after renal trauma, there are no standard guidelines for monitoring blood pressure after renal injury, although the AUA and the European Association of Urology recommend monitoring for 1 year in children who sustain renal trauma.[33, 71] Hypertension may develop from 2 days to 32 years following renal trauma, and hence long-term yearly blood pressure monitoring is recommended.[72]

A pediatric study evaluated data on 171 children with renal injuries for a period of 20 years to determine which injury grades require follow-up. The authors determined that grade IV and V injuries warrant close follow-up based on risk of adverse outcomes.[73] In this study 6 patients (4%) with grade IV–V renal injuries were newly hypertensive at follow-up.

PREVENTION

Most cases of blunt trauma are due to motor vehicle accidents. The mainstay of prevention lies in the use of seat belts, defensive driving, safer vehicles and safer roads.[74] Front and side airbags have substantially decreased the risk of renal injury.[75] Programs aimed at reducing the incidence and severity of traffic accidents are underway.

Injuries sustained from bicycle related accidents contribute significantly to the incidence of trauma. In an effort to decrease the number of bicycle accidents metropolitan areas continue to develop bicycle infrastructure dedicated to active commuting and recreation. Finally, there are ongoing efforts and studies to limit gun violence and to raise awareness of violence as a widespread public health problem.

DID YOU KNOW?

- Clinicians should use non-invasive management strategies in hemodynamically stable patients with renal injury.
- The surgical team must perform immediate intervention (surgery or angioembolization in select situations) in hemodynamically unstable patients with no or transient response to resuscitation.
- Renal trauma may increase subsequent development of hypertension.

Appendix. 2018 AAST kidney injury scale

Grade	Description of Injury
I	Subcapsular hematoma and/or parenchymal contusion without laceration
II	Perirenal hematoma confined to Gerota fascia Renal parenchymal laceration ≤1 cm depth without urinary extravasation
III	Renal parenchymal laceration >1.0 cm parenchymal depth without collecting system rupture or urinary extravasation Any injury in the presence of a kidney vascular injury or active bleeding contained within Gerota fascia
IV	Parenchymal laceration extending into urinary/collecting system with urinary extravasation Renal pelvic laceration and/or complete ureteropelvic disruption Segmental renal vein or artery injury Active bleeding beyond Gerota fascia into retroperitoneum or peritoneum Segmental or complete kidney infarction(s) due to vessel thrombosis without active bleeding
V	Main renal artery or vein laceration or avulsion of hilum Devascularized kidney with active bleeding Shattered kidney with loss of identifiable parenchymal renal anatomy

*Advance 1 grade for bilateral injuries up to grade 3.

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Study Questions Volume 39 Lesson 28

1. A 35-year-old woman was involved in a motor vehicle accident. In the trauma bay she is stable and urinalysis demonstrates microscopic hematuria. The additional absolute criterion that should be present to obtain diagnostic imaging with intravenous contrast enhanced CT is
   a. flank pain
   b. pneumothorax
   c. systolic blood pressure <90 mm Hg
   d. concurrent abdominal organ injury

2. A 55-year-old woman was in a motor vehicle accident. She is hemodynamically unstable and taken for immediate exploration, where she is noted to have a splenic injury and undergoes splenectomy. She is taken to the intensive care unit and is unresponsive to resuscitation efforts, a Foley catheter is placed and she has gross hematuria. CT demonstrates active extravasation from the left main renal artery with a grade IV renal injury, as well as a previously unrecognized bowel injury. The next step is
   a. observation
   b. repeat CT with delayed imaging
   c. angioembolization after the surgery team repairs bowel injury
   d. surgical exploration at the same time the surgery team repairs bowel injury

3. A 65-year-old woman was in a motor vehicle accident. She is hemodynamically unstable and taken for immediate exploration, where she is noted to have a splenic injury and undergoes splenectomy. She is taken to the intensive care unit and she becomes hemodynamically unstable with transient response to resuscitation efforts. A Foley catheter is placed and she has gross hematuria. She is sent for immediate CT, and the urology team is called after her blood pressure drops while she is undergoing CT. CT reveals a grade IV renal injury and no other source of bleeding. The next step following resuscitation is
   a. continue to observe, and recommend bed rest for 48 hours with serial hemoglobin/hematocrit
   b. continue to observe, recommend bed rest for 48 hours with serial hemoglobin/hematocrit and repeat CT in 24 hours
   c. angioembolization
   d. surgical exploration

4. A 30-year-old man was stabbed in the anterior abdomen. He is hemodynamically unstable at presentation and taken for immediate exploration with the trauma team. On exploration there is a pulsatile hematoma that is expanding in the retroperitoneum and you are called. The patient is actively being resuscitated and demonstrates some response intraoperatively. The next step is
   a. observation
   b. angioembolization
   c. one-shot intravenous pyelogram
   d. explore the retroperitoneum

5. A 24-year-old man was involved in a collision with a vehicle while riding a bike. He is hemodynamically unstable at initial presentation but responsive to resuscitation. He undergoes CT, which demonstrates a grade IV renal laceration with urinary extravasation from a renal calyx. The next step is
   a. admit for observation, repeat CT pending clinical course
   b. consult interventional radiology for nephrostomy tube placement
   c. take for urgent ureteral stent placement
   d. take for urgent repair of calyceal rupture

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