Upper Urinary Tract Trauma: Kidney and Ureters

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Summary

In this section of the core curriculum, we will discuss upper urinary tract trauma. Proper management of renal and ureteral trauma relies largely on obtaining accurate staging of injury severity and consideration of the patient's overall clinical stability. The mechanism of injury (blunt, penetrating, iatrogenic, etc) often influences management. Because of the diversity in clinical presentation of upper urinary tract trauma, an understanding of broad diagnostic techniques and indications for various treatment modalities is necessary for optimal patient care.

1. Renal Trauma

See **Consults and Emergencies: Upper Urinary Tract and Retroperitoneal Hemorrhage**

See **Consults and Emergencies: Urologic Trauma**

See AUA Update Series: Renal Trauma Vol 33, Lesson 1, 2014

See **AUA Urotrauma Guideline (2020)**[1]

1.1 Introduction

Contemporary management of renal trauma has largely shifted toward non-operative management, even for high grade (AAST Grade IV-V) injuries, with the ultimate goal of maximal preservation of functional renal tissue.[2] To successfully manage renal trauma, the clinician must have a solid understanding of proper radiographic imaging, available management options, and indications for intervention.

Epidemiology

The incidence of renal trauma is between 0.3-1.2%.[3,4] Following abdominal trauma, the kidneys are the second most common visceral organ to be injured and account for 24% of injuries.[5] In a review of

9,002 renal injuries using a multicenter national trauma database, nearly 80% of renal trauma was caused from a blunt etiology with 70% of cases occurring among men. [4]

The American Association for the Surgery of Trauma (AAST) Organ Injury Scale for renal trauma was originally described in 1989 and is the preferred method to stage renal injuries.[6] Using a multicenter national trauma database, 80% of renal injuries were low to intermediate grade (AAST 1-3). [4] **Approximately 90% of all renal injuries were managed conservatively in this series, highlighting that most renal trauma will not require an intervention.** Nephrectomy rates following renal injury are low (0.8-12.7%).[3,4,7,8,9,10] A contemporary series from 14 Level I trauma centers suggests nephrectomy rates are 15% and 62% for grade IV or V injuries.[10] Avoiding opening the retroperitoneum during abdominal explorations for trauma may further reduce the nephrectomy rate.[11] With the increasing availability and utilization of angioembolization, conservative management is typically the initial management of choice even for higher grade injury. [12] Conservative management for high-grade renal trauma was not associated with an increased hospital length of stay compared to renal exploration.[13]

1.2 Definition

The American Association for the Surgery of Trauma (AAST) Organ Injury Scale for renal trauma, initially described in 1989 and updated in 2018, has been validated as an important predictor of clinical outcome following renal injury.[14,15,16] **The system is based on a five-point grading scale, with one being the least severe and five being the most severe.** An update to the AAST grading system is now standard, as the quality of multi-phase computed tomography has enabled better recognition and characterization of renal injuries (**Table 1**).[17]

When the patient's clinical status does not allow radiographic imaging and emergent operative exploration is indicated, the surgeon can assign a stage to the renal injury in the operating room during renal exploration.

Table 1: Revised American Association for the Surgery of Trauma (AAST) Organ Injury Severity Score for the kidney (2018)

Grade	Type	Description
I	Parenchyma	Subcapsular hematoma and/or contusion, nonexpanding without parenchymal laceration
	Collecting System	No Injury
II	Parenchyma	Laceration < 1 cm in depth and into cortex, perirenal hematoma confined within the perirenal fascia
	Collecting System	No Injury
III	Parenchyma	Laceration > 1 cm in depth, hematoma contained within the perirenal fascia
	Collecting System	No Injury
IV	Parenchyma	• Laceration through the parenchyma into the urinary collecting system** • Vascular injury to segmental renal artery or vein • Segmental infarctions without associated active bleeding (i.e. due to vessel thrombosis) • Active bleeding extending beyond the perirenal fascia (i.e. into the retroperitoneum or peritoneum)
	Collecting System	• Laceration, one or more into the collecting system with urinary extravasation** • Renal pelvis laceration and/or complete ureteral pelvic disruption

V	Vascular	• Shattered kidney • Avulsion of renal hilum or laceration of the main renal artery or vein: devascularisation of a kidney due to hilar injury • Devascularized kidney with active bleeding

* A renal unit can sustain more than one grade of injury and should be classified by the higher grade of renal injury

** **These injuries are the same as the original AAST staging system**.[8]

1.3 Anatomy

See Reference 18

See Core Curriculum **Anatomy & Physiology Kidney, Adrenal, Ureter**

The kidneys are paired organs in the retroperitoneum with the left kidney slightly superior to the position of the right kidney.[19] The upper pole of the kidney is typically more medial than the lower pole. The adrenal glands lie just superior and each kidney rests anterior to the psoas muscle. On the right, the liver rests superiorly and its edge drapes anterior to the kidney. The descending portion of the duodenum is anterior and medial to the right kidney, intimate with Gerota's fascia. On the left, the spleen is superior and slightly medial to the upper pole of the kidney. The tail of the pancreas extends to the left renal hilum often following the medial border of the upper pole, and the greater curvature of the stomach lies at the superior-medial border. The ascending and descending colon are anterior to the right and left kidneys, respectively.

The kidneys are highly vascular and receive 20% of the cardiac output. Classically, the renal vein is anterior to the renal artery and collecting system. Accessory main renal arteries and veins can exist, with accessory renal arteries being most common. The right renal artery normally passes posterior to the inferior vena cava. The renal artery branches into five segmental arterial branches. There is one posterior branch and four anterior branches.

The left renal vein normally crosses anterior to the aorta and posterior to the superior mesenteric artery. The left renal vein is longer than the right renal vein. The following veins drain into the left renal vein: gonadal (inferiorly), adrenal (superiorly), and often lumbar (posteriorly). The gonadal vein occasionally drains from the right renal vein but classically will arise directly from the inferior vena cava. [19] It should be noted that there can be significant heterogeneity in renal anatomy, including duplicated vessels, collecting system anomalies/duplication, ectopia, fusion, and malrotation anomalies which emphasizes the need for accurate diagnostic imaging prior to intervention so long as the patient is clinically stable.

1.4 Etiology

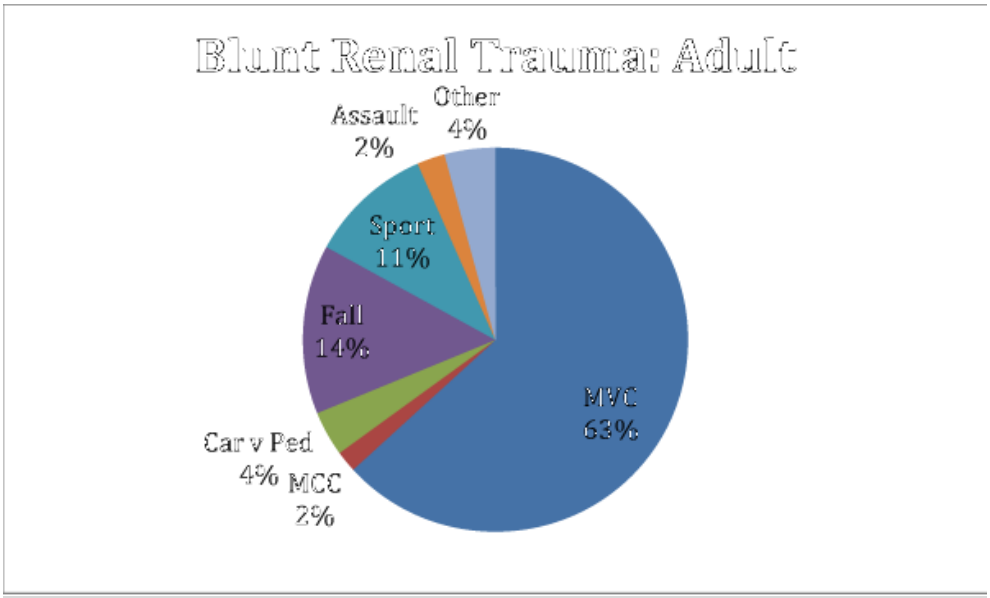

Figure 1: Demographics of adult renal trauma[20]

Blunt:

Blunt trauma is more common than penetrating renal trauma and is less commonly associated with concomitant injuries than penetrating injuries (**Figure 1**)**.** However, as the severity of renal injury increases, the likelihood of concomitant solid organ injury increases.[9,21] Essentially, the increased force required to create higher graderenal injuries suggests a more powerful mechanism of injury in general. A systematic review of 9,119 adult renal injuries in the existing literature revealed that blunt renal injury is most commonly caused by motor vehicle crashes (63%), falls (43%), sports (11%), and pedestrian injury (4%). [20]

Penetrating:

Penetrating renal injuries are more commonly due to gunshot wounds than stab wounds (65% vs. 35%, respectively).[20] Adjacent organs are commonly injured and have a higher grade of renal injury. In one study of 123 patients with penetrating renal injury, 81% sustained AAST grades III-V. [22] Another 9 year review of penetrating renal trauma showed that nearly 70% of stab wounds were successfully managed non-operatively compared with 40% of GSWs. GSW injured patients were found to have higher overall injury severity scores, AAST renal trauma score, greater need for transfusion (70% v 30%), longer hospital stay, and greater mortality (12.5% v 0%) when compared to stab wounds. [23] Nonoperative management of penetrating injuries is considered safe in selected patients; however, such injuries are a primary reason for the higher surgical exploration rates following penetrating renal trauma.

1.5 Presentation

See Reference 24

Upon arrival in the emergency department, initial multidisciplinary evaluation and stabilization of the trauma patient should include the ABCDEs: airway, breathing, circulation, disability and environment

following Advanced Trauma Life Support protocols. Following the initial survey, the physician should pay close attention to the mechanism of trauma, blunt or penetrating, as well as physical exam findings in considering possible renal injury.[25]

Further diagnostic information is gathered during the focused urologic physical examination. **In patients with a history of blunt trauma key findings include: injury mechanism (MVC, fall, hit by object, etc), location of impact, flank ecchymosis and gross or microscopic hematuria .**[26] (**Figure 2**)

Figure 2: Characteristic presentation of flank ecchymosis which should raise the clinical suspicion for renal trauma. Courtesy of Dr. Faris

Concomitant injuries (such as lower rib fracture which can suggest renal parenchymal lacerations) and the exact mechanism of injury (i.e., rapid deceleration injury that leads to renal pedicle disruption) are also important clinical findings that should alert the urologist to potential renal injury. In penetrating injury, the location of entry or exit wounds can indicate possible organs that were injured, especially when hemodynamic instability precludes radiographic imaging. Penetrating trauma to both the anterior or posterior axillary line can coincide with renal pedicle or renal parenchymal injury, respectively.

Detection of hematuria is most sensitive during the initial emergency department evaluation (prior to fluid resuscitation); however, the degree of hematuria does not correlate with the degree of renal

injury.[26]

1.6 Diagnosis and Imaging Studies

See Reference 27

See Core Curriculum **Computed Tomography (CT)**

There are several well-established clinical indications for renal imaging following blunt and penetrating injury. In the patient with a blunt trauma mechanism, indications to order radiologic imaging include the following: [26]

- **Gross hematuria in an otherwise stable patient**
- **Hemodynamic instability (SBP < 90 mm Hg) and microscopic hematuria**
- **Injury mechanism or physical exam finding suspicious for renal injury (rapid deceleration, significant blow to flank, rib fracture, significant flank ecchymosis, penetrating injury of abdomen, flank, or lower chest)** .

Patients who sustain a penetrating injury that are hemodynamically stable should undergo renal imaging with any degree of hematuria (gross or microscopic).

Computed tomography with IV contrast is the gold standard radiographic modality to evaluate renal injuries and should include immediate (arteriovenous) and delayed (excretory) contrast phases.[28] The early arterial phase allows for the detection of intravascular contrast excretion, and the delayed images allow for opacification and detection of renal collecting system injury. [28,29]

The presence or absence of a functioning contralateral kidney should be assessed before renal exploration ipsilateral to the injury. The “one-shot” intravenous urogram (2 cc/kg IV contrast followed by a single abdominal radiograph 10 minutes later) can be useful to demonstrate the presence of an uninjured contralateral kidney when pre-operative radiographic imaging is not performed. Manual palpation of the contralateral kidney during exploratory laparotomy can also suffice however, a robust psoas muscle and an atrophic kidney could cause false reassurance.[26]

Other common methods of renal imaging, ultrasound, angiography, and MRI, have a limited role in evaluating the acutely injured patient. Renal angiography with possible selective angioembolization can be considered in hemodynamically stable patients with specific findings on cross sectional imaging (hematoma > 4cm in retroperitoneum, contrast extravasation or “blush” on CT) or ongoing need for blood transfusions.

1.7 Management

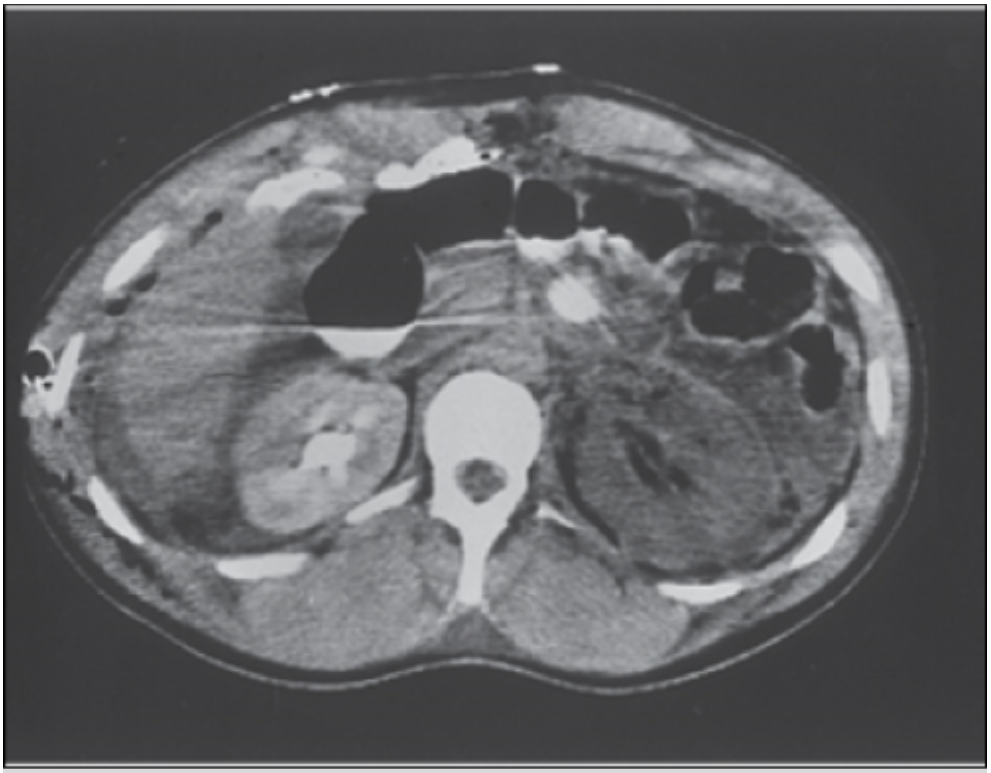

Figure 3: Left kidney is devascularized following a rapid deceleration injury to the renal hilum, resulting in acute renal artery thrombosis (Note “Cortical Rim Sign” on the left).

Figure 4: Left segmental renal vascular injury with no evidence of perirenal hematoma. The patient was successfully managed with conservative measures.

See Reference 30

General Concepts:

In many centers, the acute management of trauma patients is algorithm driven. Renal trauma is no different. Blunt trauma is the most common cause of renal injury and over the past decade, non-operative management of blunt renal trauma has become the standard of care in most cases. Algorithms for management revolve around injury staging using cross sectional, contrast enhanced imaging with delayed phase.[25] Those patients who are hemodynamically stable and have low grade injuries are observed. Patients who are hemodynamically unstable and/or do not respond to resuscitation must have immediate intervention with either surgery or angioembolization depending on the scenario and availability of services. Hemodynamically unstable patients, who proceed directly to the operating room, should undergo exploration if any of the absolute criteria for surgical management are met, even among high-grade blunt injuries. Indications for renal exploration include the following:

Absolute: (1) **expanding hematoma,** (2) **pulsatile hematoma,** (3) **persistent renal bleeding**[31]

Relative: (1) **persistent urine extravasation unresponsive to conservative measures (ie stent, IR drain, catheter, and/or PCN as clinically indicated)** (2) **significant non-viable renal parenchyma tissue,** (3) **major and/or complex (hilar, segmental) arterial injury,** (4) **incomplete renal staging or diagnostic uncertainty**[31]

Of note, emerging evidence may suggest nephrectomy independently is associated with increased mortality risk in the setting of trauma, so renal preservation should be encouraged if at all possible.[32] Renal vascular injury is very uncommon and can have various presentations upon radiographic imaging. Radiographic findings may include: large perirenal hematoma with associated intravascular contrast extravasation following a renal pedicle injury or renal artery thrombus resulting in absence of retroperitoneal hematoma (**Figure 3**). Often the latter is associated with only enhancement of the renal capsule and totally devitalized appearing renal parenchyma known as the “cortical rim sign”.

Thrombosis of segmental renal arteries following blunt injury typically presents as a wedge-shaped defect on the arterial CT phase and is best managed non-operatively (**Figure 4**). It is uncommon that these segmental renal artery injuries require intervention.[33]

To reduce the possibility of renal vascular hemorrhage following blunt renal parenchymal injury, early renal angiography with the aim of selective angioembolization should be considered in specific circumstances. CT radiographic criteria noted to increase the positive predictive value of diagnostic angiography include: intravascular contrast extravasation, perirenal hematoma rim distance > 3.5 cm, and medial hematoma. [34,35] The need for two units RBC transfusion was an important predictor in recent studies and a nomogram has been developed to incorporate these factors into predictors for intervention after renal trauma.[36] The combination of transfusion requirements and CT findings had a higher positive predictive value for diagnostic angiography leading to angioembolization than isolated clinical/radiographic findings. [37,38] Indeed, the newest AUA guidelines incorporate this data and

recommend immediate intervention with angioembolization or surgery for patients with large perirenal hematoma (> 4 cm) and/or vascular extravasation with AAST grade 3-5 injuries. [39]

Caution is advised for patients treated primarily with angioembolization for grade III-V injury given a lack of data regarding effectiveness in this population. Small multi-institutional series suggest 23-27% required either repeated angioembolization or exploratory laparotomy.[40,41] Patients with higher AAST grade, hemodynamic instability, and urinary extravasation were more likely to fail initial angioembolization.

Penetrating renal trauma is predominately caused by gunshot wounds or stabbings. These resulting injuries are typically higher-grade and have an increased rate of surgical exploration. Non-operative management is not contraindicated; however, it is less common than in blunt trauma. **Due to the blast effect of gunshot wounds, non-operative management has a higher complication rate due to associated tissue damage.** As such, non-operative management of simple penetrating injuries, like stab wounds, has been more successful in comparison.[23,42]

Indications for surgical exploration:

Surgeons can manage most blunt and select penetrating renal injuries in a non-operative fashion. In patients who proceed directly to the operating room without radiographic imaging, renal exploration is sometimes necessary. These patients in particular may have expanding, pulsatile, uncontrolled retroperitoneal hematoma or renal pedicle avulsion. Those patients who meet the criteria for damage control management may require nephrectomy if persistent hemodynamic instability is secondary to the renal injury. [43] Surgery also may be indicated in setting of angioembolization failure.[40]

Hemodynamically stable patients with renal injury may have other relative indications for surgical or radiological intervention in both the acute and sub-acute setting. In the acute setting, these include: coexisting abdominal organ injury, e.g., bowel, liver, spleen and/or other abdominal viscous injury, or renal artery thrombosis either bilateral or in a solitary kidney.[44]

In the sub-acute setting, patients with large renal pelvic laceration or ureteropelvic junction disruption, should have further diagnostic studies and may require surgical repair. Typically lacerations or disruptions have excretory contrast extravasation (especially medially) or absence of contrast entering the ureter on renal trauma imaging. Persistent renal vascular injury in the face of failed angiographic intervention often requires surgical exploration and repair or nephrectomy. Early surgical intervention, with partial or simple nephrectomy, should be considered in patients with devitalized renal parenchyma and active urine extravasation on renal trauma imaging.

Finally, patients may require a delayed surgical intervention due to continued urinary extravasation or fistula despite prior endoscopic or percutaneous urinary diversion. (**Figure 5**) Delayed nephrectomy may be required in those patients with a history of perinephric or perihilar hematoma and renovascular mediated hypertension (Page Kidney). This often manifests as poorly controlled hypertension often refractory to multiple medications and a prior history of high grade renal injury.

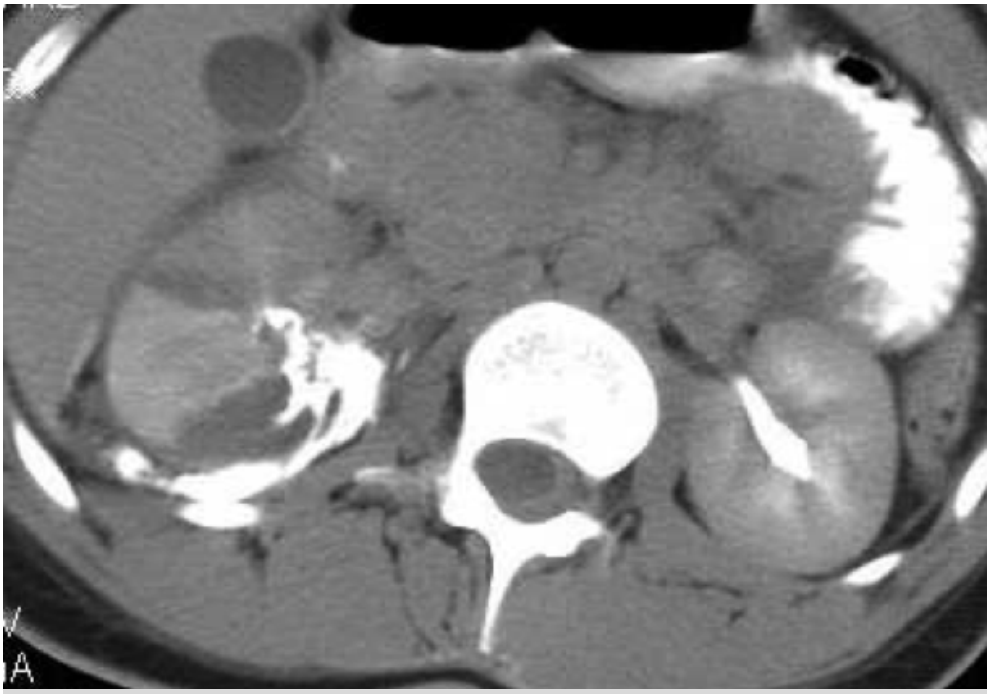

Figure 5: Patient with a Grade IV renal laceration initially underwent surveillance, but later developed elevated white blood cell count and urinoma treated successfully with ureteral stenting. Courtesy of Dr. Faris

Operative Approach to Renal Trauma:

Prior to renal exploration, confirmation of the presence or absence of a contralateral kidney is recommended. This can be performed either through imaging modalities (preferred) or direct palpation. Conflicting data exists regarding the utility of a strict protocol of preliminary vascular control in lieu of elective vascular control; however, vascular control is recommended when there is concern for vascular bleeding during renal reconstruction. Although some studies support early vascular control to reduce the need for nephrectomy, conflicting reports refute the advantage of early renal vessel control. [45,46,47,48] Early renal vessel control is obtained by midline vascular control (transmesenteric) or following reflection of the colon.

Care should be taken to preserve the renal capsule when mobilizing Gerota's fascia, as the integrity of the renal capsule aids in renal reconstruction. Debridement of ischemic or non-viable parenchyma is necessary prior to renal reconstruction to ensure successful outcome. This is especially necessary following gunshot wounds, as the kinetic energy transfer from blast effect can result in significant tissue damage. [31] Bullets themselves rarely cause harm if left in situ so heroic attempts at removal of fragments is not required. [49] Stab wounds are often associated with less tissue damage and may be amenable to simple tissue approximation of entry/exit wounds.[42] Associated large/small bowel or pancreatic injury is not a contraindication for renal reconstruction. In the setting of concomitant solid organ or intraperitoneal injuries, expert opinion would suggest copious irrigation of the area of repair is advisable, and separation by interposition of omentum, peritoneal flaps or perirenal/pararenal adipose may reduce fistula risk and contain or prevent small

volume urine extravasation. **Repair of obvious collecting system injuries should be performed with fine (4-0 or 5-0) absorbable suture.**

1.8 Special Considerations for the Pediatric Patient

See AUA Core Curriculum: **Pediatric Trauma**.

Pediatric patients, less than 18 years old, should have renal imaging with the finding of gross or microscopic hematuria, defined as greater than 50 RBCs/hpf, independent of blood pressure measurements[50] In this age group, hypotension is not a useful criterion to determine the need for radiographic imaging due to the high levels of circulating catecholamines following trauma. Furthermore, mechanism is an important consideration in these patients due to different anatomical structure at this age, i.e. higher likelihood of ureteropelvic junction disruption in rapid deceleration injury. Ultimately, guidelines specifically for the pediatric patients have been developed consisting of three major themes:

(1) In pediatric patients with blunt renal trauma of any grade nonoperative management is recommended versus operative management in hemodynamically stable patients (2) hemodynamically stable pediatric patients with high-grade (AAST grade III-V) renal injuries, angioembolization is recommended versus surgical intervention for ongoing or delayed bleeding.[51] (3) finally, routine blood pressure checks are recommended to diagnose hypertension which may occur in ~ 5% of pediatric patients.[52]

1.9 Complications

A repeat CT with delayed images should be performed 48-72 hours following non-operative management of a grade 4 or higher injury or for clinical signs of complications (e.g., fever, worsening flank pain, ongoing blood loss, abdominal distention).[26] 12.5% of asymptomatic patients with high-grade renal trauma ultimately required surgical intervention in a multi-center series.[53] If the collecting system injury progresses on subsequent radiographic imaging or if patients develop complications such as enlarging urinoma, fever, increasing pain, ileus, fistula or infection, cystoscopy with ureteral stent placement and concomitant urethral catheter should be considered to reduce the development of an urinoma or perinephric abscess. A perinephric abscess associated with devitalized renal parenchyma may require more aggressive therapy, such as perinephric drain, percutaneous nephrostomy, or surgical exploration.

Delayed hemorrhage is more common following penetrating renal injuries that are managed in a non-operative fashion. Patients with high-risk injuries should have repeat imaging and consideration for diagnostic angiography to reduce the incidence of delayed hemorrhage. The most common sources of delayed renal hemorrhage are ruptured arteriovenous fistula or pseudoaneurysm. Both are best managed with angioembolization.

Hypertension following renal injury is secondary to chronic renal compression (Page kidney) or chronic renal artery compression/ischemia (Goldblatt kidney). Both scenarios lead to activation of the renin-angiotensin system and can be treated by debridement of perinephric hematoma,

revascularization, nephrectomy, or medical therapy. Periodic blood pressure screening is recommended following renal injury to monitor for the development of hypertension, especially in the case of high grade renal trauma or in patients with a midpole medial laceration and medial blood on CT . [54]

2. Ureteral Trauma

AUA2019 Crossfire Controversies in Urology Ureteral reimplantation should be robotic

Crossfire in Urology - Robotic reconstruction

Consults and Emergencies – Intraoperative

Anatomy & Physiology Kidney, Adrenal, Ureter

2.1 Introduction

Ureteral injuries are a rare component of genitourinary trauma, comprising only 1-2.5% of all urologic injuries. [55,56] **Ureteral injuries themselves are typically not life threatening, but they often present in the context of polytrauma**. Penetrating ureteral injuries predominate, most commonly because of gunshot wounds. Blunt ureteral injuries are rarer, with most being caused by high energy motor vehicle collisions.[56] Iatrogenic ureteral injuries may result from endoscopic procedures of the urinary tract or any surgical procedure involving the retroperitoneum or pelvis. Signs and symptoms of ureteral injury are nonspecific and thus a high index of suspicion is required to minimize sequela of missed ureteral injury.

2.2 Definition

Ureteral injuries occur on a spectrum dependent on the etiology and severity of the traumatic event. The American Association for the Surgery of Trauma (AAST) grading scale for ureteral injuries is as follows:

- Grade I – Hematoma – Contusion or Hematoma without devascularization
- Grade II – Laceration – Less than 50% transection
- Grade III – Laceration - ≥ 50% transection
- Grade IV – Laceration – Compete transection with <2 cm of devascularization
- Grade V – Laceration – Avulsion with >2 cm of devascularization

The mechanism, anatomic location and severity of ureteral injuries are highly variable and dictate the optimal management strategies and potential complications.

a. Blunt injuries: contusion, laceration, and avulsion.
b. Penetrating injuries: laceration, transection, and blast injury with potential delayed complications due to devascularization (urinoma, fistula, stenosis, etc.).
c. Iatrogenic endoscopic injuries range from minor mucosal abrasions, to lacerations, to complete avulsion. [57] Iatrogenic surgical injuries include ligation, laceration, transection,

devascularization, and thermal injury.

2.3 Anatomy

See Core Curriculum **Anatomy & Physiology Kidney, Adrenal, Ureter**

The ureters lie completely within the retroperitoneum, beginning near the upper level of the 3rd lumbar vertebral body and ending deep within the true pelvis. **The ureters are well protected by the psoas musculature and spinal column/bony pelvis posteriorly and the abdominal contents anteriorly, thus explaining their relatively low risk of injury from both blunt and penetrating trauma**.[58]

Important anatomic landmarks for ureteral identification include: anteromedial to the medial edge of the lower pole of the kidney, posterior to the gonadal vessels and mesocolon, anterior to the common iliac vessels near the iliac bifurcation, and posterior to the vas deferens in males and uterine vessels in females.

The blood supply to the ureter is provided by multiple small unnamed arteries which approach the ureter throughout its course and intercommunicate through a rich anastomotic network within the periureteral arterial plexus. While individual arterial contributions to the plexus vary, arterial supply is typically from medial vessels proximally (renal artery, aorta, gonadal artery) and lateral vessels distally (inferior/superior vesical arteries, internal iliac artery). Venous drainage occurs by way of a rich periureteral network, exiting through small unnamed veins throughout the course of the ureter.

2.4 Etiology

***Blunt*: Ureteral injury due to blunt trauma is exceedingly rare**. When it occurs, it is typically in the context of high energy and/or rapid deceleration injury (such as a highway speed motor vehicle accident) leading to complex, multisystem trauma. Disruption of the ureteropelvic junction is the most common type of blunt ureteral injury.[59]

***Penetrating*:** The risk of ureteral injury from penetrating abdominopelvic trauma depends on the trajectory of the injury, type of penetrating object (i.e. stab vs. gunshot wound), and energy of the projectile (i.e. low velocity handgun vs. high velocity rifle). The close anatomic relationships of the ureters to the major abdominal vessels and gastrointestinal structures explain the high rate of bowel and vascular injury in patients with penetrating ureteral trauma.

***Iatrogenic*: Ureteral injury can complicate a wide variety of open, laparoscopic, and endoscopic procedures**. Endoscopic ureteral injuries are frequently encountered during ureteroscopic stone surgery and are typically managed with termination of the procedure after placement of a ureteral stent to allow for ureteral healing.[57] Open and laparoscopic ureteral injuries are most frequently encountered during colorectal and gynecological procedures but may be encountered during any abdominal or pelvic surgery near the ureters or posterior bladder wall.[60] There may be higher rates of ureteral injury during laparoscopic pelvic surgery, particularly

hysterectomy.[61,62]

At times, urologists may be called upon to provide ureteral catheterization to aid in ureter identification during complex surgery.[63] Preoperative stenting may allow for earlier identification of ureteral injury but has not been proven to reduce injury rates; stenting does incur a higher risk of acute kidney injury and increased hospital costs. [64]

2.5 Presentation

See Reference 65

Although not life threatening themselves, most non-iatrogenic ureteral injuries present in the context of complex multisystem trauma. The initial evaluation of patients at risk for ureteral injury must follow ATLS protocol administered by the trauma team to allow for initial resuscitation and to identify the multiple injuries frequently associated with ureteral trauma. [66] Subsequent **evaluation for ureteral injury must be performed in the context of the patient's other injuries and not interfere with evaluation and management of more life threatening conditions**. As such, it is not uncommon to delay definitive repair of a ureteral injury until the patient is clinically stable.

While a detailed history is often not obtainable from severely injured trauma patients, **the urologist should obtain details of the mechanism of injury to determine the patient's risk of ureteral involvement**. Ureteral injury due to blunt trauma is rare and typically occurs only in the context of high energy injuries or in a patient with preexisting anatomic abnormalities of the urinary collecting system. For penetrating injuries, important historical information includes trajectory of the injury, type of penetrating object, and energy of the projectile.

Physical findings of ureteral injury are nonspecific. Gross and/or microscopic hematuria may indicate ureteral injury but its absence is not sufficient to exclude ureteral injury.[67] Complete UPJ avulsion is unlikely to present with hematuria.[68] Ecchymosis and/or the presence of an entrance/exit wound on the flank should increase the level of suspicion for ureteral injury.

2.6 Diagnosis and Imaging Studies

Figure 6A: Computed tomography scans demonstrating contrast extravasation at the level of a penetrating distal ureteral injury

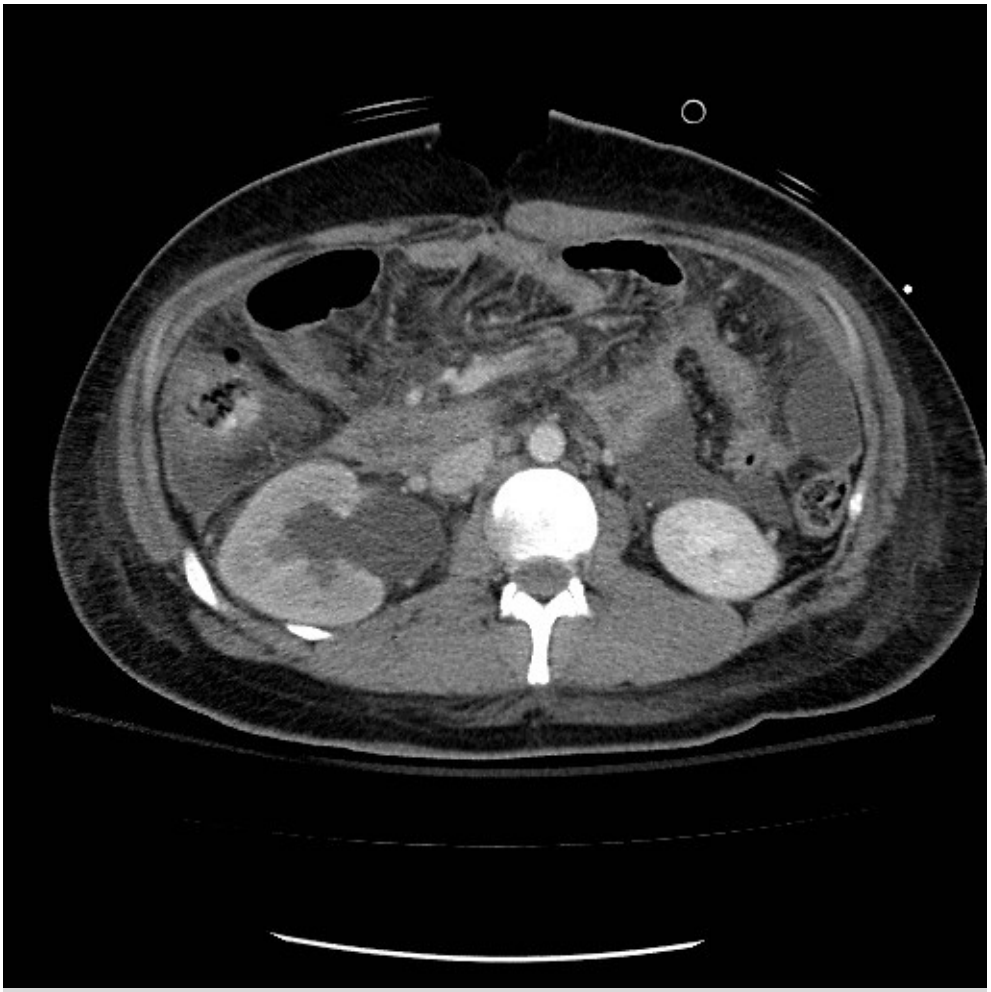

Figure 6B: Computed tomography scans demonstrating an ipsilateral delayed pyelogram and hydronephrosis in a patient with delayed recognition of a **penetrating mid-ureteral injury**

Figure 6C: Intraoperative retrograde pyelography revealing left sided ureteric defect from blast injury ultimately successfully repaired with psoas hitch and reimplantation. Courtesy of Dr. Andrew J Cohen.

Hemodynamically stable patients at risk for ureteral injury (based on the history/exam criteria discussed above) require ureteral imaging.[1] **Intravenous contrast enhanced abdominal/pelvic computed tomography scan with 10-minute delayed images (CT urogram or CT IVP) is the modality of choice to evaluate the collecting system and ureter**. Findings suggestive of ureteral injury include contrast extravasation (**Figure 6a**), ipsilateral delayed pyelogram (**Figure 6b**), ipsilateral hydronephrosis (**Figure 6b**), and absence of contrast distal to the area of suspected injury. Retrograde pyelography can be performed in equivocal cases but may be logistically challenging in the **acute trauma** setting. (**Figure 6c**) Single-shot intraoperative intravenous pyelography is an unreliable method to exclude ureteral injury and should not be used for this purpose.[1,67]

2.7 Management

Blunt/Penetrating Ureteral Injuries: Hemodynamically unstable patients with abdominopelvic injury frequently proceed directly to laparotomy with the trauma surgery team before radiographic staging to evaluate for ureteral injury. The physician should suspect a ureteral injury when a penetrating object's trajectory approaches the ureter's location or structures near the ureter are injured. **When a ureteral injury is suspected, it should be identified and directly inspected.**[1] Methylene blue or indigo carmine injected intravenously or directly into the renal pelvis may help identify small lacerations or incomplete transections. Blast effect from high-velocity projectiles may lead to ureteral contusion and/or ischemia even if laceration does not occur. Indocyanine Green (ICG) angiography can be considered to evaluate for ischemic or devascularized ureteral segments. Ureteral injuries can be managed with either immediate resection with repair or ureteral stenting with observation. The decision on which approach usually depends on the viability of the ureter and its surrounding tissues as well as the stability of the patient. [1]

Immediate management of ureteral injuries, when possible, is intended to minimize and/or prevent complications. Complications from unrecognized injury or delayed repair include urinoma, abscess, fistula, ureteral obstruction, and renal failure. Simple ureteral lacerations should be closed transversely rather than longitudinally to prevent luminal narrowing. Transections should be debrided, spatulated, and re-anastomosed over a ureteral stent using absorbable sutures (typically 4-0 or 5-0). Proximal injuries are typically repaired by primary ureteroureterostomy (UU). For distal ureteral transections, a primary ureteroneocystostomy may allow the surgeon to repair the injury using a larger circumference anastomosis to reduce the risk of ureteral stricture. Longer ureteral defects may require adjunctive maneuvers such as vesicopsoas hitch or Boari bladder flap. These techniques allow for reconstruction at the time of injury even for quite involved distal and mid ureteral injuries. More complicated reconstruction including transureteroureterostomy, ileal interposition, and renal autotransplantation are best performed in a delayed setting. [1]

While ureteral repair is typically performed at the time of initial trauma laparotomy, overall patient status may not allow the time needed for formal repair. In the situation of a damage control setting, principles may mandate a 48-72 hour delay to allow for correction of trauma-induced hypothermia, hypotension, and/or coagulopathy. In a damage control situation, urine should be temporarily diverted away from the site of injury with externalized ureteral catheter secured to the proximal end of the ureteral defect. Alternatively clipping or tying the ureter proximal to the site of injury and planning for percutaneous nephrostomy tube with delayed reconstruction is a reasonable option.

Unfortunately, **many ureteral injuries are not identified at initial presentation, and thus remain unrecognized until complications occur (particularly iatrogenic injuries)**. In such situations, it is often best to divert the urine (via nephrostomy and/or stent), drain the urinoma, and treat any associated infection. Ultimately, many of these injuries will result in ureteral stricture, ureteral fistula (to skin, bowel, vagina, etc.) and/or complete ureteral obliteration requiring reconstructive surgery in a delayed setting. **The reconstruction technique required is dependent on several factors:**

length of defect, location of defect, bladder capacity/mobility, history of previous abdominopelvic surgery/radiation therapy, presence/anatomy of contralateral renal unit, bowel function, and overall function of the obstructed renal unit. Short proximal ureteral defects are typically amenable to direct ureteroureterostomy, pyeloplasty, or ureterocalycostomy. Longer proximal ureteral defects require more complex reconstructive procedures such as a long Boari flap, augmented anastomotic ureteroureterostomy with buccal mucosa graft, appendiceal onlay, ileal interposition, or renal autotransplantation. Short defects of the middle ureter can typically be repaired with ureteroureterostomy, but longer mid-ureteral defects will require vesicopsoas hitch +/- Boari flap or transureteroureterostomy depending on the size/mobility of the bladder and anatomy of the contralateral ureter. Ureteroneocystostomy +/- psoas hitch is the preferred repair for distal ureteral defects of any length. At specialized centers, buccal mucosa graft is utilized in well selected clinical scenarios with intermediate term (median 27 months) success of 87%.[69] Appendiceal interposition and/or onlay has also been described.[70] Such reconstructive surgeries are increasingly performed using robotic techniques when appropriate.[71] Nephrectomy may be the best option for some patients, particularly those with normal overall renal function and significant functional loss of the ipsilateral renal unit.

Iatrogenic Ureteral Injuries: When recognized during the primary operation, iatrogenic ureteral injuries are best managed immediately. Lacerations and transections should be repaired over a ureteral stent. In the case of a thermal/crush/ligature injury, the consulting urologist can stent or primarily repair the injury at their discretion. Utilization of a drain to check for urine leak using creatinine levels could assist the post-operative management of these ureteral injuries. Of note **endoscopic injuries typically heal with stenting alone**.

Iatrogenic ureteral injuries are often not recognized at the time of the initial operation and present days or weeks later with urinoma, incisional drainage, high surgical drain output, urinary fistula, abscess, sepsis, ileus, and/or azotemia. Retrograde pyelography is the preferred diagnostic modality in this setting and allows for the ability to attempt stent placement at the time of diagnosis. When iatrogenic ureteral injuries are recognized within the first postoperative week, immediate re-exploration and repair can be considered. However, if the diagnosis is delayed further, or if an infection is present, the urine should be diverted with a nephrostomy tube and/or stent. A delayed reconstruction is preferred at least 2-3 months after the complication is recognized and diverted. [1]

2.8 Special Considerations for the Pediatric Patient

Ureteral injuries in children (especially young children and infants) are rare. Data exploring any differences between adult and childhood ureteral injury is limited and thus it is difficult to draw any conclusions about whether the evaluation and management of these two groups should differ.[72] In general, the previously discussed principles (based on adult data) should provide a useful guide for the urologist asked to assist with the rare pediatric patient who presents with ureteral injury. Due to the more mobile spine and less retroperitoneal fat in children, they may be more susceptible to blunt ureteral trauma, particularly UPJ disruption.[73] Given lower incidence of pelvic surgery in children,

iatrogenic injury rates are likely lower than those for adults. However, increasing numbers of pediatric patients undergo ureteroscopy for stone disease and incur ureteral injury rates akin to those in adults.[74]

Key Takeaways

- Renal trauma is typically managed conservatively but requires accurate grading with a delayed phase CT (IVP or Urogram) at presentation.
- High grade renal trauma may require intervention if persistent urinary extravasation or hemodynamic instability.
- Ureteral injuries are rare and often non-life threatening; however, they can be a significant source of morbidity if unrecognized and/or untreated.
- Delayed phase CT (IVP or Urogram) or Retrograde pyelography should be performed in any patient with suspected ureteral injury

Presentations

Renal, Ureter Presentation 1

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