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Evaluation and Management of Non-iatrogenic Ureteral Trauma

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Abstract
Purpose of Review Ureteral injuries are rare and represent a minority of genitourinary injuries in trauma patients. Their association with complex polytrauma and propensity for delayed recognition present diagnostic and therapeutic challenges. Herein, we present a review of the available literature on the evaluation and management of non-iatrogenic ureteral injuries.
Recent Findings The incidence of traumatic ureteral injury appears to be increasing as a result of improved trauma survivability and enhanced imaging techniques. While most of the ureteral trauma literature reports on penetrating mechanisms of injury, blunt ureteral injuries are typically associated with more severe injury scores. Diagnosing traumatic ureteral injuries continues to be challenging and clinical suspicion should guide subsequent evaluation based on the patient's condition. Computerized tomography with intravenous contrast and excretory phase imaging is the gold standard for evaluating suspected ureteral injuries in clinically stable trauma patients. Many ureteral injuries will still be diagnosed intraoperatively and may be successfully temporized or definitively reconstructed acutely. In unstable patients, damage control principles have been adapted to ureteral trauma permitting delayed reconstruction. Delayed diagnosis of these injuries has been associated with increased morbidity, mortality, length of stay, and renal loss.
Summary Traumatic ureteral injuries are rare and require a high index of suspicion. Patient physiology may guide the evaluation and eventual treatment of these injuries. Improved detection, management, and vigilance for potential complications of traumatic ureteral injuries can improve patient outcomes and decreased resource utilization.

Keywords Genitourinary trauma · Ureteral injury · Ureteral trauma · Ureteral reconstruction

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Introduction

Trauma is a frequent cause of death and disability. Injuries were the third most common causes of death worldwide, accounting for approximately 9% of mortalities in 2015 [1]. In 2013, injuries accounted for 39.4 million emergency department visits [2]. Genitourinary injuries are identified in 10% of hospitalized trauma patients [3•], typically in the context of complex polytrauma [4]. However, traumatic ureteral injuries are rare, historically representing less than 1% of all genitourinary injuries [5, 6]. Siram and colleagues demonstrated a higher rate of traumatic ureteral injury at 2.5% in a retrospective analysis of almost 23,000 genitourinary injuries identified in the National Trauma Data Bank (NTDB) from 2002 to 2006 [7]. The greater frequency of traumatic ureteral injury is believed to be secondary to enhanced imaging techniques and improved trauma survivability.

Anatomic Considerations

Located in the retroperitoneum, the proximal ureter begins at the ureteropelvic junction and transitions to the mid-ureter as it crosses the sacroiliac joint. The middle ureter spans the

sacroiliac region to become the distal ureter as it enters the true pelvis. The lumbar spine is medial and posterior to the abdominal portion of the ureter. The "pelvic ureter" begins as it crosses the common iliac vessels and is associated with the ilium posteriolaterally and the sacrum posteriomedialy. Abdominal and pelvic organs overlie the ureter throughout its course with potential for iatrogenic injury during colorectal, gynecologic, and vascular surgery. However, the deep, well-protected nature of the ureter likely explains its lower vulnerability to violent trauma when compared to other genitourinary organs.

Mechanisms of Injury

Penetrating ureteral trauma is the most common mechanism of injury [5, 6, 8, 9]. The majority of ureteral trauma literature reports on penetrating trauma with most studies focusing on gunshot wounds alone and while blunt trauma injuries may be underreported (Table 1) [6]. Nonetheless, ureteral injuries occur in only 2–4% of abdominal gunshot wounds [10, 11].

Due to points of fixation at the ureteropelvic and ureterovesical junctions, the ureter is susceptible to avulsion injury as a result of rapid deceleration or violent motor vehicle trauma [12]. Additionally, severe distraction of skeletal structures can lacerate or avulse the ureter. Whereas historical studies estimated blunt ureteral trauma to comprise only 4–6% of all traumatic ureteral injuries [6, 9], a restrospective analysis of the NTDB reported a much higher frequency of 38% [7]. Another key finding of this study was the significant difference in Injury Severity Score (ISS) for blunt (21.5) vs. penetrating (16) injuries, further highlighting the severity of trauma associated with blunt ureteral injury.

Concomitant Injuries

Approximately 90% of traumatic ureteral injuries occur in the setting of polytrauma [13]. Comorbid injuries are not surprising given the ureters' anatomic proximity to intraabdominal, retroperitoneal, vascular, and skeletal structures. The American Association for the Surgery of Trauma (AAST) grades ureteral injuries based on the presence and size of the laceration/transection as well as the associated devascularization adjacent to the transection (Table 2) [14]. This classification scheme has been previously validated and demonstrated to correlate with complexity of ureteral repair and number of associated injuries [9]. Bowel injuries are the most common injuries associated with ureteral trauma. In the largest single-institution series on gunshot wounds to the ureter, bowel injuries represented 56% of all observed comorbid injuries [15]. While penetrating ureteral injuries are commonly associated with bowel and vascular injuries, blunt ureteral injuries are more likely to be associated with pelvic and/or vertebral fractures. Additionally, blunt trauma is more frequently associated with arterial injury compared to the venous injuries more common to penetrating trauma. In fact, the 38% incidence of vascular injury in the NTDB series is more than twice the previously reported incidence of the largest single-institution series [15].

Diagnosis

Immediate signs and symptoms of traumatic ureteral injury are non-specific. In penetrating trauma, the trajectory of the missile or stab wound should raise suspicion for potential ureteral injury. Physical exam findings for blunt trauma are less reliable, though flank ecchymosis or a "seatbelt sign" may be associated with abdominal or genitourinary organ injury. The absence of hematuria in 15–56% of traumatic ureteral injuries is a factor in their delayed diagnosis [13, 15, 16]. The presence of hematuria certainly warrants evaluation, either preoperative or intraoperative, depending on the specific clinical condition of each patient.

Diagnostic Imaging

The sensitivity of perioperative testing in the setting of ureteral injury has been reported as low as 20% [17]. Earlier studies have reported an unacceptably high non-diagnostic rate for intravenous urography (IVU) with an estimated cumulative sensitivity of 51% [18]. Nonetheless, the "complete IVU" is recommended as a reliable and accurate modality in stable patients [19]. Findings suggestive of traumatic ureteral injury on IVP include frank extravasation of contrast, non-visualization of the affected system, hydronephrosis, and medial deviation of the ureter [15]. Finally, despite its high accuracy, retrograde pyelography is cumbersome and thus not typically appropriate in the acute trauma setting.

Well-established clinical practice guidelines recommend IV contrast enhanced abdominal/pelvic CT with 10-min delayed imaging for stable trauma patients with suspected ureteral injuries [20••, 21••]. Ureteral injuries should be suspected based on the clinical criteria discussed above (high-energy blunt trauma, penetrating abdominopelvic injuries). CT findings suggestive of traumatic ureteral injury include contrast extravasation, ipsilateral delayed pyelogram, ipsilateral hydronephrosis, and lack of contrast in the ureter distal to the suspected injury. When contrast is not given or 10-min delayed images are not obtained, findings are less specific, including subtle perinephric stranding, low-density retroperitoneal fluid, ureteral dilation/deviation, or bladder displacement [7, 22].

Intraoperative Diagnosis

A significant proportion of patients with traumatic ureteral injuries will proceed directly to the operating room for exploratory laparotomy prior to radiographic evaluation due to patient instability or mechanism of injury. International series on traumatic ureteral injuries report rates of intraoperative diagnosis of 40–85% in patients without preoperative imaging [23, 24]. The sensitivity of intraoperative identification was reported at 88.9% on a meta-analysis [16] of the traumatic ureteral injury literature with a range of 63–95% on selected series [5, 25]. Hence, intraoperative diagnosis remains the most common and reliable means of diagnosing traumatic ureteral injuries. During exploratory laparotomy, identification of a retroperitoneal hematoma or fluid collection along with organ injuries in the vicinity of the ureter raises the suspicion of traumatic ureteral injury.

The American Urological Association (AUA) Urotrauma Guideline states that direct ureteral inspection during laparotomy is necessary for all patients with suspected ureteral injury without preoperative imaging [20]. Various adjunctive techniques can be utilized to aid in detection of these injuries at the time of operative exploration. Intravenous methylene blue or indigo carmine may aid in detection of transecting ureteral injuries but will not be diagnostic of ureteral contusions. The same dyes can be injected into the renal pelvis or ureter but care must be taken to avoid spillage as this can obscure the operative field. Retrograde instillation of dyes or contrast can also be performed via cystoscopic or open cannulation of the ureters but this approach may also miss significant ureteral contusions. Finally, the intraoperative "one-shot" IVP does not reliably exclude traumatic ureteral injuries and thus should not be used to exclude ureteral injury [19].

Delayed Diagnosis

The rate of missed ureteral injury varies greatly across single-institution series but is on average 38% on review of the traumatic ureteral injury literature [13]. Kunkle et al. cited patient intraoperative factors germane to the complex polytrauma patient such as bleeding, hypotension, coagulopathy, and hypothermia contributing to missed ureteral injuries. Surgeon-specific factors include inadequate retroperitoneal exploration and inappropriately decreased index of suspicion for ureteral injury. Proximal ureteral injuries are more likely to go unrecognized due to their less accessible location and greater potential for association with a perinephric hematoma if a concomitant renal laceration is present [16, 17]. Finally, some traumatic ureteral injuries may be dynamic in their manifestation, particularly when caused by gunshot wounds or high-energy blast mechanisms. Cass reported on a series of 12 patients with ureteral contusions secondary to gunshot wounds. Two injuries were repaired primarily at initial exploration due to intraoperative appearance of the ureter while the remaining ten injuries were observed, of which, two eventually developed urinary fistula [26].

Diagnosis of missed ureteral injuries presents unique management challenges in the short- and long-term. Signs and symptoms may be non-specific, including flank or abdominal pain, anorexia, ileus, fever, and in severe cases of ongoing urinary extravasation, peritonitis, and/or sepsis. Elevated serum creatinine can be indicative of peritoneal absorption of extravasated urine, while more specific findings include urinary drainage from postsurgical drains or urinary-cutaneous fistula. Urine leak is confirmed by sending the effluent for creatinine. Management is discussed below but in all cases begins with urinary diversion (with nephrostomy tube or ureteral stent), urinoma drainage, and appropriate treatment of the associated infection.

Management

The consultant urologist must always remember that Advanced Trauma and Life Support guidelines will dictate initial evaluation and treatment of all trauma patients and that any genitourinary injuries must be managed without violating Advanced Trauma and Life Support (ATLS) and damage control surgical principles. Life-threatening injuries take precedence and patient physiology may further influence the ability to assess for traumatic ureteral injury in an acute versus a delayed setting. In the exploratory surgical setting, careful attention must be paid to location of ureteral injury along with degree of tissue devitalization. Furthermore, in penetrating trauma secondary to gunshot wounds, ballistic effects of the missile must be well understood as direct and indirect cavitary forces can have immediate and potentially delayed tissue effects. Santucci et al. have thoroughly examined wound ballistics and report on several accepted fallacies of gunshot injuries. Specifically, their review highlights the difference between high and low-velocity ballistics in terms of tissue effect and explains how the effects of high-velocity missiles are overestimated and misrepresented in the literature. Further attention is given to the quality of the missile (jacketed vs. unjacketed) as experimental studies and clinical correlates clearly demonstrate the profound tissue effects of unjacketed projectiles. The collective evidence presented as part of their review challenges the dogmatic recommendation for wide excision of tissue in high-velocity wounds in favor of judicious debridement to limit the extent of iatrogenic injury at the time of surgical exploration [27].

Ureteral Contusions

Ureteral contusions are the least severe of the traumatic injuries; however, their evaluation and management require a certain degree of clinical intuition and vigilance. There is controversy regarding optimal management of these injuries. Potential treatment options in the intraoperative setting include observation, excision, and debridement with ureteroureterostomy or endoscopic management with indwelling ureteral stent. The decision to employ any of these options is based on clinical assessment of tissue compromise and as previously discussed; even "normal" appearing ureters at exploration may eventually manifest delayed complications such as urinary extravasation and/or ureteral stricture. It is noteworthy that in the ureteral contusion series by Cass, only two injuries were repaired primarily and none of the remaining injuries were treated with ureteral stenting. It is the expert opinion of the AUA Urotrauma panel that all ureteral contusions diagnosed at laparotomy should be treated with ureteral stenting or resection with primary repair based on ureteral viability and clinical scenario [20]. There is no reported recommendation for duration of indwelling stent and stent removal along with choice of follow-up imaging is at the discretion of the clinician.

Surgical Principles

The extent of tissue devitalization and the level of the ureteral injury will influence the plan for ureteral reconstruction. In stable patients, it is recommended that traumatic ureteral lacerations be managed at the time of laparotomy. The AUA Urotrauma guidelines further recommend that injuries proximal to the iliac vessels be repaired primarily over a ureteral stent whereas injuries distal to the iliac vessels should be treated with ureteral reimplantation or primary repair over a stent when possible [20]. Depending on the length of ureteral loss, primary ureteral repair, or reimplantation may be challenging, if not impossible. Techniques such as bladder mobilization and downward nephropexy have been described in ureteral reconstruction and may be used alone or in conjunction with other accepted ureteral reimplant techniques such as bladder hitch or flap [28]. Careful ureteral mobilization should aim to preserve the adventitial blood supply. After judicious debridement of non-viable tissue, a widely spatulated, tension-free, and watertight anastomosis should be performed in order to optimize the success of the reconstruction. In situations of extensive ureteral loss, transureteroureterostomy can be performed but is rarely reported in the setting of acute trauma while ileal interposition is discouraged in the acute trauma setting due to the need for bowel preparation and contraindication in the setting of impaired renal function [29]. Ureteral repairs may be retroperitonealized or wrapped with omentum to reduce the risk of leakage and improve vascularity [28]. Passive or closed-suction drains can be placed in the area of the repair and may be of diagnostic value in identifying delayed necrosis leading to anastomotic failure and urine leak. Given the association of ureteral trauma with hollow viscus injuries and intraabdominal contamination, there may be hesitation to undertake definitive ureteral reconstructions in this setting. Azimuddin and colleagues refute this notion and provide evidence for reconstructive success even in the setting of gross intraabdominal contamination with the repair failures in this series not correlated with degree of intraabdominal soilage [25]. Ultimately, proper assessment of the severity of ureteral injury along with meticulous surgical technique results in successful repairs reported at approximately 80% across multiple series [10, 15, 30].

Damage Control Surgery

Over the past 25 years, the principle of damage control surgery has evolved to include applications for multiple surgical subspecialties in the care of the complex polytrauma patient. Basic tenets of damage control surgery include abbreviated laparotomy with control of life-threatening injuries and contamination (phase 1) followed by correction of coagulopathy, metabolic derangements, and normalization of body temperature (phase 2). Usually by 72 h, the third phase of damage control surgery typically involves multiple definitive surgeries in preparation for prolonged critical care support or eventual recovery [31]. The association between traumatic ureteral injuries with overall severity of trauma has been previously established with mean ISS > 15 (major trauma) reported by Best et al. in their validation of the AAST classification for ureteral injuries [9]. Initial applications of damage control principles in urologic trauma included exteriorization of the transected ureter as a "tube ureterostomy" or management with stenting of partial injuries [25]. Smith et al. describe the utilization of "single J" stents for tube ureterostomy and secure the stent to the proximal end of the ureteral defect with a permanent suture to prevent dislodgement [32]. Pediatric feeding tubes can be used in a similar manner when urinary stents are not available. Tube ureterostomy prevents urinary extravasation while facilitating ureteral reconstruction during a subsequent laparotomy once the patient has been stabilized. When patient instability, comorbid injuries, and/or the degree of ureteral loss prohibit reconstruction in the acute phase, the ureter should be ligated at the proximal end of the defect. A percutaneous nephrostomy tube is then placed which will facilitate urinary drainage until reconstruction (or nephrectomy) is performed after initial recovery and rehabilitation.

Delayed Management of Injuries

Whether a traumatic ureteral injury was missed on initial evaluation, manifested in a delayed fashion or failed primary

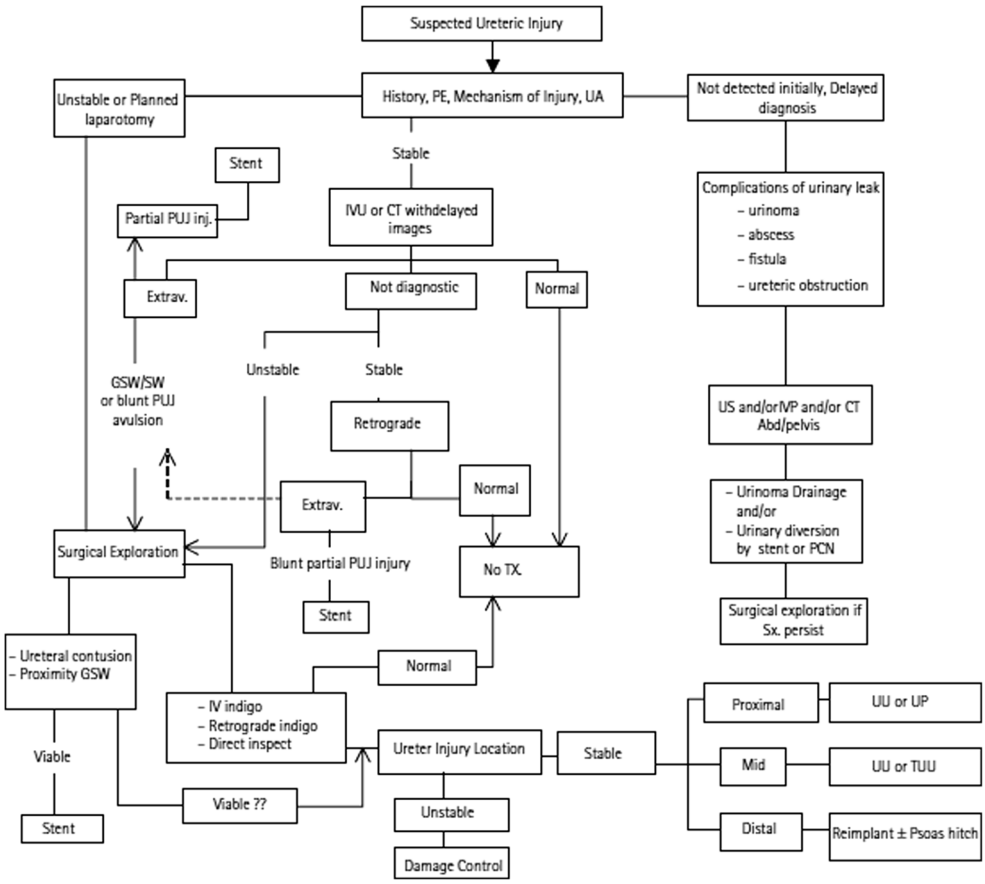

Fig. 1 Diagnosis and treatment algorithm for suspected ureteral injury proposed by Brandes et al. [19] (adapted with permission)

repair; recognition may occur well beyond the acute phase of resuscitation or surgery. The AUA Urotrauma guidelines recommend attempts at ureteral stenting for incomplete ureteral injuries diagnosed postoperatively or in a delayed setting with use of percutaneous nephrostomy and delayed reconstruction if these attempts are not possible or unsuccessful [20••].

Morbidity and Mortality

Patients with traumatic ureteral injuries can have significant morbidity and potential mortality due to the association of these injuries with complex polytrauma. While the increased incidence of traumatic ureteral injuries likely reflects improved survivability due to advances in trauma and critical care, the morbidity secondary to ureteral injuries can be mitigated by timely recognition and treatment. Most of the morbidity and reported complications can be attributed to delayed recognition [15, 29]. The severity of morbidity can range from urinary tract infection to sepsis, peritonitis, urinary fistula, ureteral stricture, or renal loss. Early case series report nephrectomy rates as high as 44% for ureteral injuries diagnosed in a delayed setting [33]. Contemporary studies estimate the rate of nephrectomy for delayed-diagnosed injuries at 18.4% compared to 2.4% for those recognized early [16]. Delayed diagnosis ultimately results in prolonged hospital course. NTDB analysis revealed an average length of hospitalization of 17.2 days for penetrating trauma compared to 13.5 days for blunt mechanisms in spite of lower median injury severity scores for penetrating trauma [7]. These length of hospitalization estimates are lower than the previously reported 19 days for immediately recognized injuries and further emphasize the significance of delayed detection of injuries with a mean length of hospitalization of 36.6 days on meta-analysis [16]. Finally, the current impact of traumatic ureteral injuries can be assessed through analysis of resource utilization and cost, with estimated costs of $25,000 for treating a single ureteral injury [15].

Pereira and colleagues reported the rate of complications related to traumatic ureteral injuries at 36.2%. The clinical impact of the high complication rate is uncertain given inconsistent reporting and potentially broad range of possible complications. Fraga et al. reported a 55% rate of complications with factors such as shock on admission, ISS > 25, colonic injuries, and delayed diagnosis of ureteral injury as factors contributing to complications [23].

All-cause mortality in traumatic ureteral injury literature is variable. Siram and colleagues reported 9% mortality for blunt and a 6% rate for penetrating trauma based on NTDB data. The traumatic ureteral injury literature reports an associated

17% mortality [13] in patients with these injuries, while Kunkle and colleagues further stratified mortality rates at 6.1 and 13.2% for early diagnosed and missed ureteral injuries, respectively [16]. However, the true impact of ureteral injury on mortality is unclear as it is most likely related to associated life-threatening injuries.

Summary and Conclusions

Ureteral injuries due to external trauma are rare but their association with complex polytrauma and propensity for delayed recognition pose diagnostic and therapeutic challenges. A high index of suspicion for ureteral injury must be maintained with patient physiology often guiding the evaluation and eventual management of these injuries (Fig. 1) [19]. Stable trauma patients not proceeding directly to laparotomy can be imaged without significant interruption to acute care and evaluation should include contrast enhanced CT with delayed phase imaging to appropriately assess for ureteral injury. Intraoperative detection of traumatic ureteral injury is highly sensitive and prompt repair of detected ureteral injuries should be undertaken whenever possible. When needed, damage control principles are applicable to urologic trauma and can help optimize conditions for eventual repair of recognized injuries. With improved detection, management, and vigilance for potential complications of traumatic ureteral injuries, the morbidity, cost, and potential mortality of these injuries can be decreased and lead to improved patient outcomes.

Compliance with Ethical Standards

Conflict of Interest None.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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Appendix

Table 1 Mechanism and anatomic location of ureteral trauma: literature reprts

Reference	Number of cases	Gunshot wound	Stab wound	Blunt injury	Upper ureter	Mid-ureter	Distal ureter
Elliot [18]	36	22	9	5	25	3	8
Bright [19]	59	52	5	2	19	23	17
Brandes [20]	12	8	4	NPS	2	7	3
Cambell [21]	15	12	0	3	7	4	4
Carlton [22]	39	36	1	2	NA	NA	NA
DiGiacomo [23]	23	23	NPS	NPS	NA	NA	NA
Eikenberg [24]	17	17	NPS	NPS	6	2	9
Ghali [25]	8	12	0	6	7	0	1
Holden [26]	63	63	NPS	NPS	20	27	16
Lankford [27]	10	10	NPS	NPS	6	3	1
Liroff [28]	20	20	NPS	NPS	5	11	4
Medina [29]	20	15	4	1	NA	NA	NA
Palmer [30]	20	19	1	NPS	3	7	10
Perez-Brayfield [31]	55	55	NPS	NPS	23	11	21
Peterson [32]	18	17	1	NPS	5	7	6
Azimuddin [33]	21	19	2	NPS	6	8	7
Stutzman [34]	22	22	NPS	NPS	6	3	13
Steers [35]	18	17	0	1	12	4	2
Rober [36]	16	16	NPS	NPS	8	4	4
Velmahos [37]	41	39	2	NPS	NA	NA	NA
Walker [38]	27	24	0	3	10	12	5
Totals	560	508 (90.7%)	29 (5.2%)	23 (4.1%)	170 (39%)	136 (31%)	131 (30%)

Review of ureteral trauma literature stratified by mechanism and location of injury (Elliott, McAninch [12])

NPS not part of study, *NA* not available

Table 2 Ureter organ injury scale

Grade[a]	Injury type	Description of injury	ICD-9	AIS-85	AIS-90
I	Hematoma	Contusion of hematoma without devascularization	867.2/867.3	2	2
II	Laceration	< 50% transection	867.2/867.3	2	2
III	Laceration	> 50% transection	867.2/867.3	3	3
IV	Laceration	Complete transection with with 2-cm devascularization	867.2/867.3	3	3
V	Laceration	Avulsion with > 2 cm of devascularization	867.2/867.3	3	3

American Association for the Surgery of Trauma Classification for Ureteral Injury (adapted with permission from Moore [14]

[a] Advance one grade if multiple lesion exits

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