Curr Trauma Rep (2015) 1:119–124
DOI 10.1007/s40719-015-0015-x

PENETRATING INJURIES TO HOLLOW ABDOMINAL VISCERA (K INABA, SECTION EDITOR)

Penetrating Trauma to the Ureter, Bladder, and Urethra

Uwais B. Zaid[1] · **David B. Bayne**[1] · **Catherine R. Harris**[1] · **Amjad Alwaal**[1] · **Jack W. McAninch**[1] · **Benjamin N. Breyer**[1]

Published online: 14 April 2015

Abstract We describe the epidemiology, diagnosis, and management of adult civilian penetrating trauma to the ureter, bladder, and urethra. Trauma is a significant source of death and morbidity. Genitourinary injuries are present in 10 % of penetrating trauma cases. Prompt recognition and appropriate management of genitourinary injuries, which are often masked or overlooked due to concomitant injuries, are essential to minimize morbidity. Penetrating trauma most commonly results from gunshot wounds or stab wounds. Compared to blunt trauma, these typically require surgical exploration. An understanding of anatomy and a high index of suspicion are necessary for prompt recognition of genitourinary injuries.

Keywords Genitourinary trauma · Ureter · Bladder · Urethra

Introduction

Trauma accounts for 10 % of mortality in the USA and results in $406 billion annually in health care costs and productivity losses [1•]. Trauma is the leading cause of death in individuals between the ages of 1 and 44 years [2]. Genitourinary injuries are present in about 10 % of trauma cases [1•].

Penetrating trauma most commonly results from either a gunshot wound (GSW) or stab wound (SW). With GSWs, trauma results from high energy transfer to the body and adjacent structures and has an unpredictable path. Additionally, release of secondary projectiles such as bone fragments causes further injury to adjacent organs. Extent of injury from GSW is related to bullet caliber, velocity, and distance [3]. SWs result from a multitude of objects and typically have a more predictable path. As opposed to blunt trauma, penetrating trauma generally requires surgical exploration [3].

Lower genitourinary tract trauma can be both life threatening and significantly impact quality of life. Rapid diagnosis and appropriate management is crucial in limiting mortality and morbidity. We review the epidemiology, diagnosis, and management of ureteral, bladder, and urethral penetrating injuries in the adult civilian setting.

This article is part of the Topical Collection on *Penetrating Injuries to Hollow Abdominal Viscera*

✉ Benjamin N. Breyer
bbreyer@urology.ucsf.edu

[1] Department of Urology, University of California, San Francisco, 400 Parnassus Avenue, Suite A-610, Box 0738, San Francisco, CA 94143-0738, USA

Ureteral Injuries

Background and Epidemiology

Ureteral injuries account for less than 1 % of all urologic trauma [3]. Injuries are relatively uncommon because the ureters are well protected in the retroperitoneum by the bony pelvis, psoas muscle, and vertebrae. However, a missed ureteral injury can result in significant morbidity. Additionally, because the ureters are well protected, injuries to these structures are often associated with significant concomitant injuries whose management dictates immediate patient care [3].

In a retrospective analysis of the American National Trauma Data Bank from 2002 to 2006, approximately 2.5 % of all genitourinary trauma involved ureteral injury (582 of 22,706) [4•]. Of these, 61.5 % were secondary to penetrating trauma, and the most common mechanisms were gunshot wounds and stab wounds [5]. The majority of patients with penetrating ureteral trauma are young males (mean age 27) [6]. In one

series, the majority of injuries were short segment losses of the upper ureter, while in another, the majority were involving the distal ureter [7, 8]. Penetrating ureteral trauma is often associated with bowel and vascular (more commonly venous) injuries [9]. The mortality rate for patients with penetrating ureteral injuries in one series was 6 % [10].

Diagnosis

Patients with ureteral trauma often have other major intra-abdominal injuries, and the multiple traumas can contribute to a delay in the diagnosis and management of the ureteral injury [11]. Symptoms of ureteral injury may include hematuria and hypotension, although these are not always present [12]. In one series, gross hematuria was found in only 43 % of ureteral injuries [3]. Typically, there are no classic signs or symptoms for ureteral injuries. Rather, one needs to have a high index of suspicion in penetrating abdominal injuries.

In the trauma setting, computed tomography urogram (CTU) can often be performed quickly and gives detailed anatomic information. The AUA trauma guidelines recommend performing abdominal/pelvic CT with intravenous contrast and delayed scans (urogram) for all stable patients with suspected ureteral trauma [5]. Radiographic CT findings suggestive of ureteral injury include contrast extravasation, delayed pyelogram, hydronephrosis, and lack of contrast in the ureter distal to the injury. Intraoperatively, in the stable patient, single shot IVP may give anatomic and functional information. This involves giving 2 cc/kg intravenous contrast as a bolus with a single abdominal x-ray shot at about 10 min to delineate the presence and function of a contralateral renal unit which may influence management of the injured unit. One may also consider a retrograde pyelogram for further anatomic delineation [3].

In unstable patients with multiple injuries, traumatic ureteral injuries may be diagnosed during exploratory laparotomy, either by direct inspection or by visualizing extravasation of renally excreted intravenous dye such as methylene blue or indigo carmine [3].

The American Association for the Surgery of Trauma (AAST) has a five-point grading scale for ureteral trauma, described in Table 1.

Table 1 AAST ureteral trauma grading score

Grade	Injury
I	Periureteral hematoma
II	Laceration <50 % of circumference
III	Laceration >50 % of circumference
IV	Complete tear <2 cm devascularized
V	Complete tear >2 cm devascularized

Management

Ureteral injuries that go undiagnosed may lead to a urine leak, urinoma formation and sepsis [4•]. Other complications include formation of periureteral abscess, ureteral fistula, and stricture which may result in renal failure [3]. The primary goal for repair is to maintain renal drainage. Management options depend on the site of injury, extent of devitalized ureter, and concomitant injuries. Basic surgical principals include a tension-free anastomosis, debridement of devitalized tissues, spatulation of each end, and water-tight anastomosis. We use absorbable sutures (5–0 PDS) with magnification for repair. We believe that the use of ureteral stents can facilitate healing, although some urologists have voiced concern that stents may lead to stricture formation, inflammatory reaction, and discomfort [3]. We feel that the benefits outweigh the risks and advocate use of stents in ureteral injury repair.

Reconstructive options for the ureters depend on the location and length of injury. Injuries in the upper third of the ureter may be managed with either a uretero-ureterostomy or uretero-pyelostomy. In the middle third, one may consider a uretero-ureterostomy, transuretero-ureterostomy, or rarely a Boari flap. In the lower third, options including a ureteroneocystotomy (primary reimplant) or psoas hitch [3]. Options depend on bladder size and mobility. For ureteral injuries that are longer, one may consider an appendiceal or ileal ureter conduit or potentially a renal autotransplant. In the acute trauma setting, these are not ideal options and should be reserved for reconstruction once the patient is more stable. In the unstable patient, surgery may need to be delayed with temporary urinary drainage by a percutaneous nephrostomy tube.

Bladder Injuries

Background and Epidemiology

A review of 2693 trauma laparotomies at a level 1 trauma center found a 4.1 % rate of bladder injuries [13]. Of these, 51.3 % were the result of penetrating injuries. Additionally, in this series, there was a 41.3 % association with rectal injuries [13]. Among these penetrating injuries, 80 % resulted from GSW and 20.9 % from SW [13]. However, a review of the 8565 documented bladder injures in the National Trauma Data Bank found that 85 % of the bladder injuries were caused by blunt trauma [4•]. In blunt trauma cases, bladder injury was reported in 1.6 % [5]. In general, although bladder injury is rare in cases of blunt trauma, patients with bladder injuries are likely to have more severe and life threatening injuries [6]. Motor vehicle crashes and pedestrian with motor vehicle collisions are the most common causes of blunt trauma resulting in bladder perforation (80 %) [1•]. In this series, while most bladder injuries resulted from blunt trauma, penetrating

trauma accounted for 14 to 51 % of bladder injuries [1•]. Although GSWs comprise 88 % of bladder injury caused by penetrating trauma, only 3.6 % of all abdominal GSW result in bladder trauma [1•]. Often, iatrogenic injuries during intra-abdominal surgery can cause bladder injury, which is correlated with procedure complexity [1•, 5].

Diagnosis

It often is difficult to evaluate for signs of bladder injury because bladder injuries are rarely isolated injuries. However, concomitant pelvic fracture, suprapubic tenderness or fullness, low urine volumes, lower abdominal bruising or swelling, and abdominal hematoma may indicate potential bladder injury [7]. Guttmann describes a triad of clinical symptoms: hematuria, suprapubic or abdominal pain, and difficulty voiding, which may not be present in all cases [8]. For instance, gross hematuria is associated with 67 to 95 % of bladder injuries [9, 10]. Additionally, the severity of blood in the urine does not correlate with the degree of bladder injury; 5 % of traumatic bladder ruptures present without gross hematuria [10]. However, bladder rupture is less likely if microscopic urine analysis shows fewer than 25 red blood cells per high-powered field [8].

One must have a high index of suspicion for bladder injury based on clinical history, physical exam findings, and laboratory values. If concern exists, bladder imaging is recommended [7]. Conventional radiography with retrograde filling of the bladder has been shown to be equivalent to CT cystogram. When done appropriately (adequate bladder distention with a subsequent drainage phase), both are highly specific and sensitive for intraperitoneal and extraperitoneal bladder injuries [12, 14, 15]. Findings indicative of bladder injury include contrast material visible outside of the bladder, which can vary depending on the location of bladder injury [12]. Thus, a good drainage film is imperative. With an intraperitoneal injury, contrast material is visible outlining the bowels. With extraperitoneal bladder injuries, contrast extravasation may be visualized in the prevesical space, anterior peritoneal space, and tracking to the superficial soft tissues of the anterior and medial thighs [12].

The AAST uses a one to five grade scaling system for bladder injury as described in Table 2.

Table 2 AAST bladder injury scale [15]

Grade	Injury
I[a]	Contusion, intramural hematoma, partial thickness laceration
II[a]	Extraperitoneal bladder wall laceration <2 cm
III	Extraperitoneal > or = to 2 cm, intraperitoneal <2 cm bladder wall laceration
IV	Intraperitoneal bladder wall laceration > or = 2 cm
V	Intraperitoneal of extraperitoneal laceration extending into bladder neck or ureteral orifice

[a] Advance one grade if multiple lesions

Management

Intraperitoneal Bladder Injuries

An absolute indication for immediate primary bladder repair is intraperitoneal bladder injury. These generally require operative management because they are unlikely to heal with drainage alone due to urine leakage into the peritoneal cavity, which can also result in urinary ascites, abdominal abscess, ileus, and sepsis. Similarly, penetrating bladder trauma generally requires exploration given its high likelihood of concomitant visceral injuries and likelihood of intraperitoneal rupture [5, 16].

Extraperitoneal Bladder Injuries

Absolute indications for repair of extraperitoneal injuries include concomitant bladder neck injury, rectal or vaginal injury, open pelvic fracture, pelvic fracture requiring open reduction and internal fixation, and bone fragments projecting into the bladder [17]. One may also consider repair of bladder rupture if the patient is already undergoing a surgical procedure where repair of the bladder is facilitated [5]. However, most extraperitoneal bladder injuries can be managed nonoperatively as urine extravasation is usually confined [5]. Injuries to the bladder neck and trigone can compromise continence and therefore generally require repair [18]. In open transvesical repairs, feeding tubes or intravenous indigo carmine or methylene blue can be used to stage the ureters for patency and to help localize the ureteral orifices.

Bladder drainage with a urethral catheter and/or suprapubic tube is important following repair of the bladder. We additionally utilize a closed suction drain placed near our repair site. The fluid from the drain is typically checked for creatinine to evaluate for a urine leak prior to drain removal. After bladder repair, postoperative cystogram is recommended in 10–14 days and has been described as early as 5–10 days after repair [17, 19]. When managing bladder trauma conservatively, decompression with a Foley catheter is recommended followed by interval cystography to assess for resolution of urine extravasation [17].

Urethral Trauma

Background and Epidemiology

Urethral injuries comprise 4 % of urologic trauma injuries and can cause substantial morbidity with marked effects on quality

of life [20]. Given longer urethral length, urethral injuries are more common in men than women. Additionally, the male urethra has less anatomic support. In patients with pelvic fractures, concomitant urethral injuries may be present in up to 25 % of men and 4.6 % of women [21]. Most urethral injuries are related to pelvic fracture and are most commonly caused by motor vehicle collisions [22]. Sixty-five percent of urethral injuries result in complete disruptions while 35 % are incomplete tears [1•]. Penetrating injuries to the anterior urethra most commonly result from GSW to the pendulous and bulbar urethra equally. In a retrospective review from the Henry Ford Center Trauma Registry, a review of 309 patients showed that the urethra was injured in 2.9 % of civilian GSW injuries [1•]. Additionally, these patients often present with concomitant lower extremity and pelvic injuries in 44 and 33 %, respectively [1•].

Anatomically, urethral injuries can be either anterior or posterior. Posterior urethral injuries occur proximal to the perineal membrane at the prostatic or membranous urethra [22]. The anterior urethra includes the bulbar and penile urethra in addition to the fossa navicularis. The bulbar segment is more anatomically fixed in place than the penile or pendulous urethra and therefore more vulnerable to crush injury. With regards to penetrating injuries, the bulbar or penile urethral are equally affected by GSWs [1•]. With regards to blunt trauma, posterior urethral injuries are four times more common than anterior urethral injuries in industrialized societies [1•]. Pubic symphysis diastasis and displaced inferomedial pubic bone fractures occur in up to 88 % of patients with urethral injury [21]. Degree of pubic symphysis diastasis directly correlates with likelihood of urethral injury [21]. Malgaigne, or vertical sheer fractures, involve breaks in multiple pelvic bones, including the pubic rami and the wing of the ipsilateral ilium or the sacrum, with associated upper displacement of the hemipelvis [21].

Diagnosis

Patients with a urethral injury may present with blood at the urethral meatus, suprapubic fullness, or urinary retention [23]. Because of concomitant injuries, if injury is thought to be due to pelvic fracture, a rectal exam must be performed to stage the rectum in men and vaginal exam to evaluate for vaginal injuries in women. The high riding prostate is an unreliable sign [23].

Evaluation of the urethra should be performed with a retrograde urethrogram (RUG). Other indications for urethral imaging include an unstable pelvis, penile fracture, or significant perineal hematoma after straddle injury. If contrast extravasation is seen, a suprapubic tube should be placed, although a single gentle pass of a Foley catheter may be attempted [22]. Our technique for performing a RUG includes placing the patient at a 45° oblique angle if possible, flex the bottom leg at 90°, and keep the top leg straight. If there is an obvious pelvic fracture but no blood at the urethral meatus, some argue attempted gentle catheterization with Foley by a urologist. If this fails, a suprapubic catheter should be placed. In women, cystourethroscopy should be considered to evaluate the bladder neck since injury here may lead to urinary incontinence [24].

In the setting of delayed urethral repair, repeat imaging with RUG and voiding cystourethrogram (VCUG) is essential to better characterize the defect length and location. In instances where visualization of the bladder neck is poor, flexible cystoscopy can be used through the suprapubic site to gain better visualization [17, 25]. MRI can be utilized to further characterize the stricture by estimating length of defect, the degree of prostatic misalignment, and the density of scar tissue, although we do not routinely use this in our practice and it may comprise an unnecessary cost [26].

AAST also uses a one to five grade scaling system for urethral injury as described in Table 3.

Management

Posterior Urethra

With injuries to the male posterior urethra, initial exploration and anastomotic repair is not performed as it results in higher rates of stricture, incontinence, and impotence [27]. Placement of a suprapubic catheter is the gold standard of care in men with posterior urethral injuries to allow for urinary diversion and clean healing of sites of injury prior to open delayed urethroplasty [9]. One may attempt endoscopic realignment of the urethra provided the patient has stable injuries that will allow for appropriate positioning. Prolonged attempts at realignment are discouraged, as they are likely associated with worse incontinence and erectile dysfunction. Patients who are successfully realigned require close follow-up as rate of future stenosis

Table 3 Urethral injury grading [15]

Grade	Injury
I	Urethral contusion, blood at meatus, retrograde normal
II	Elongation of the urethral without extravasation on urethrography
III	Extravasation of contrast on urethrography at injury site
IV	Extravasation of contrast on urethrography at injury site without bladder visualization, <2 cm
V	Complete transection with > or = 2 cm separation, extravasation into prostate or vagina

and obstruction approaches 80 % [28]. In the setting of urethral injuries where primary realignment is not possible, delayed surgical repair is the recommended treatment. These patients should initially be managed with a suprapubic catheter. In general, attempted urethral reconstruction should be delayed until 3–6 months after the injury when scar formation has stabilized and sufficient healing has occurred [29•].

Anterior Urethra

Penetrating anterior urethral injuries are more commonly managed with initial surgical exploration and primary repair. If there is incomplete disruption, one may consider catheter placement. In cases where additional injuries are present that prevent immediate surgical repair one should place a suprapubic catheter for urinary diversion and perform interval urethroplasty. In the setting of significant tissue loss from injury, suprapubic urinary diversion should be performed and definitive urethral reconstruction should be pursued at a later date.

Conclusion

Genitourinary trauma is present in 10 % of trauma cases [1•]. Penetrating trauma most commonly results from either GSW or SW. The extent of injury from GSW is related to bullet caliber, velocity, and distance [30]. SWs result from a multitude of objects and typically have a more predictable path. As opposed to blunt trauma, penetrating trauma generally requires surgical exploration [30]. A retrospective review from the San Francisco General Hospital, a level 1 trauma center, showed that 84 % of GSWs involving the lower urinary tract involved the bladder [29•]. Additionally, 80 % were associated with a concomitant bowel injury, with 34 % being a rectal injury. Bullets that went anterior to posterior were associated with intestinal injuries in 71 % of cases versus 45 % when it was posterior to anterior [29•].

Lower genitourinary tract trauma can be both life threatening and significantly impact quality of life. Rapid diagnosis and appropriate management is crucial in limiting mortality and morbidity.

Compliance with Ethics Guidelines

Conflict of Interest Uwais B. Zaid, David B. Bayne, Catherine R. Harris, Amjad Alwaal, Jack W. McAninch, and Benjamin N. Breyer declare no conflicts of interest.

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.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance

1.• McGeady JB, Breyer BN. Current epidemiology of genitourinary trauma. Urol Clin North Am. 2013;40:323–34. **Great reference giving up to date epidemiologic trends on GU trauma**.
2. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control: 10 Leading Causes of Death by Age Group, United States – 2011.
3. Pereira BM, Ogilvie MP, Gomez-Rodriguez JC, et al. A review of ureteral injuries after external trauma. Scand J Trauma Resusc Emerg Med. 2010;18:6.
4.• Deibert CM, Spencer BA. The association between operative repair of bladder injury and improved survival: results from the National Trauma Data Bank. J Urol. 2011;186:151–5. **Great reference looking at outcomes after repair**.
5. Gomez RG, Ceballos L, Coburn M, et al. Consensus statement on bladder injuries. BJU Int. 2004;94:27–32.
6. Matlock KA, Tyroch AH, Kronfol ZN, et al. Blunt traumatic bladder rupture: a 10-year perspective. Am Surg. 2013;79:589–93.
7. Morey AF, Iverson AJ, Swan A, et al. Bladder rupture after blunt trauma: guidelines for diagnostic imaging. J Trauma. 2001;51:683–6.
8. Guttmann I, Kerr HA. Blunt bladder injury. Clin Sports Med. 2013;32:239–46.
9. Brandes S, Borrelli Jr J. Pelvic fracture and associated urologic injuries. World J Surg. 2001;25:1578–87.
10. Morgan DE, Nallamala LK, Kenney PJ, et al. CT cystography: radiographic and clinical predictors of bladder rupture. AJR Am J Roentgenol. 2000;174:89–95.
11. Abou-Jaoude WA, Sugarman JM, Fallat ME, et al. Indicators of genitourinary tract injury or anomaly in cases of pediatric blunt trauma. J Pediatr Surg. 1996;31:86–9. discussion 90.
12. Quagliano PV, Delair SM, Malhotra AK. Diagnosis of blunt bladder injury: a prospective comparative study of computed tomography cystography and conventional retrograde cystography. J Trauma. 2006;61:410–21. discussion 421–2.
13. Peng MY, Parisky YR, Cornwell 3rd EE, et al. CT cystography versus conventional cystography in evaluation of bladder injury. AJR Am J Roentgenol. 1999;173:1269–72.
14. Carroll PR, McAninch JW. Major bladder trauma: the accuracy of cystography. J Urol. 1983;130:887–8.
15. Moore EE, Cogbill TH, Jurkovich GJ, et al. Organ injury scaling. III: chest wall, abdominal vascular, ureter, bladder, and urethra. J Trauma. 1992;33:337–9.
16. Tsai CH, Wang YC, Wu SC, et al. Laparoscopic repair of extraperitoneal urinary bladder rupture after blunt abdominal trauma. Am Surg. 2012;78:E385–6.
17. Mortelmans D, Messaoudi N, Jaekers J, et al. Laparoscopic repair of intraperitoneal bladder rupture after blunt abdominal trauma. Urol J. 2014;11:1338–40.
18. Kim FJ, Chammas Jr MF, Gewehr EV, et al. Laparoscopic management of intraperitoneal bladder rupture secondary to blunt abdominal trauma using intracorporeal single layer suturing technique. J Trauma. 2008;65:234–6.
19. Bariol SV, Stewart GD, Smith RD, et al. An analysis of urinary tract trauma in Scotland: impact on management and resource needs. Surgeon. 2005;3:27–30.

20. Basta AM, Blackmore CC, Wessells H. Predicting urethral injury from pelvic fracture patterns in male patients with blunt trauma. J Urol. 2007;177:571–5.
21. Mundy AR, Andrich DE. Urethral trauma. Part I: introduction, history, anatomy, pathology, assessment and emergency management. BJU Int. 2011;108:310–27.
22. Kong JP, Bultitude MF, Royce P, et al. Lower urinary tract injuries following blunt trauma: a review of contemporary management. Rev Urol. 2011;13:119–30.
23. Koraitim MM. Pelvic fracture urethral injuries: the unresolved controversy. J Urol. 1999;161:1433–41.
24. Buckley JC, Wu AK, McAninch JW. Impact of urethral ultrasonography on decision-making in anterior urethroplasty. BJU Int. 2012;109:438–42.
25. Koraitim MM, Reda IS. Role of magnetic resonance imaging in assessment of posterior urethral distraction defects. Urology. 2007;70:403–6.
26. Koraitim MM. Pelvic fracture urethral injuries: evaluation of various methods of management. J Urol. 1996;156:1288–91.
27. Leddy LS, Vanni AJ, Wessells H, et al. Outcomes of endoscopic realignment of pelvic fracture associated urethral injuries at a level 1 trauma center. J Urol. 2012;188:174–8.
28. Mundy AR, Andrich DE. Urethral trauma. Part II: types of injury and their management. BJU Int. 2011;108:630–50.
29.• Cinman NM, McAninch JW, Breyer BN, et al. Gunshot wounds to the lower urinary tract: a single-institution experience. J Trauma Acute Care Surg. 2013;74(3):725–31. **Excellent retrospective review of lower GU tract GSW injuries**.
30. Pereira BM, Reis LO, Calderan TR, et al.: Penetrating bladder trauma: a high risk factor for associated rectal injury. Adv Urol. 2014; 2014:386280