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REVIEW ARTICLE

Trauma to the bladder and ureter: a review of diagnosis, management, and prognosis

B. Phillips[1,2,3,4] · S. Holzmer[1,2,3] · L. Turco[1,2,3] · M. Mirzaie[1,2,3] · E. Mause[1,2,3] · A. Mause[1,2,3] · A. Person[1,2,3] · S. W. Leslie[2] · D. L. Cornell[1,2,3] · M. Wagner[1,2,3] · R. Bertellotti[1,2,3] · J. A. Asensio[1,2,3]

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Abstract

Background Injuries to the ureter or bladder are relatively rare. Therefore, a high level of clinical suspicion and knowledge of operative anatomy is of utmost importance for their management. Herein, a review of the literature related to the modern diagnosis, management, and prognosis for bladder and ureteral injuries is presented.

Methods A literature search was conducted through PubMed. A thorough search of the world's literature published in English was completed. Search terms included "injury, diagnosis, prognosis, and management for ureter and bladder". All years, both genders, as well as penetrating, blunt, and iatrogenic mechanisms were evaluated for inclusion. Following PRISMA guidelines, studies were selected based on relevance and then categorized.

Results 172 potentially relevant studies were identified. Given our focus on modern diagnosis and treatment, we then narrowed the studies in each category to those published within the last 30 years, resulting in a total of 26 studies largely consisting of Level IV retrospective case series. Our review found that bladder ruptures occur from penetrating, blunt, or iatrogenic mechanisms, and most are extraperitoneal (63%). Ureteral injuries are incurred from penetrating mechanisms in 77% of cases. The overall mortality rates for bladder rupture and ureteral injury were 8 and 7%, respectively.

✉ B. Phillips
bjpmd02@gmail.com

S. Holzmer
StephanieWeed@creighton.edu

L. Turco
LTurco@kumc.edu

M. Mirzaie
MinaMirzaie@creighton.edu

E. Mause
ElizabethMause@creighton.edu

A. Mause
AlisonMause@creighton.edu

A. Person
AustinPerson@creighton.edu

S. W. Leslie
StephenLeslie@creighton.edu

D. L. Cornell
David.Cornell@alegent.org

M. Wagner
Michel.Wagner@alegent.org

R. Bertellotti
Robert.Bertellotti@alegent.org

J. A. Asensio
JuanAsensio@creighton.edu

[1] Division of Trauma Surgery and Surgical Critical Care, Department of Surgery, Creighton University Medical Center, Creighton University School of Medicine, Omaha, NE, USA

[2] Division of Trauma Surgery and Surgical Critical Care, Department of Urology, Creighton University Medical Center, Creighton University School of Medicine, Omaha, NE, USA

[3] Division of Trauma Surgery and Surgical Critical Care, Department of Clinical and Translational Science, Creighton University Medical Center, Creighton University School of Medicine, Omaha, NE, USA

[4] Vice Chair of Surgery, Surgical Research, Department of Surgery, Creighton University Medical Center, Creighton University School of Medicine, 601 North 30th Street, Suite 3701, Omaha 68131-2137, NE, USA

Limitations Limitations of this article are similar to all PRISMA-guided review articles: the dependence on previously published research and availability of references.
Conclusion The bladder is injured far more often than the ureter but ureteral injuries have higher injury severity. Both of these organs can be damaged by penetrating, blunt, or iatrogenic mechanisms and surgical intervention is often required for severe ureter or bladder injuries. Since symptoms of these injuries may not always be apparent, a high level of suspicion is required for appropriate diagnosis and treatment.

Keywords Bladder trauma diagnosis · Blunt bladder trauma · Penetrating bladder trauma · Ureter trauma diagnosis · Bladder trauma prognosis · Ureter trauma prognosis · Bladder trauma management · Ureter trauma management · Blunt ureter trauma · Penetrating ureter trauma

Background

Traumatic injury to the abdomen is one of the most common reasons for hospital admission in the USA [1, 2]. Yet, less than 10% of all abdominal traumas involve injury to the genitourinary system [3]. Of genitourinary injuries, the bladder is most often injured, while ureteral injuries account for less than 1% [4]. Injuries to the bladder and ureter are graded by the American Association for Surgery of Trauma Organ Injury Scale (AAST-OIS) and may be managed according to the extent and type of injury (see Table 1) [5]. Furthermore, due to the anatomic relationship of the ureter and bladder, injury to both organs often occurs concomitantly, especially in the setting of multisystem trauma [6–8]. Given the severity of these genitourinary injuries, a high level of skill and knowledge of urologic anatomy is necessary to establish proper diagnosis and provide optimal treatment. This review of the literature evaluates modern diagnostic techniques, approaches to management, and prognoses of injuries to the ureter and bladder.

Methods

In this study, the world's literature was searched through PubMed following PRISMA guidelines. Search terms included "bladder trauma, diagnosis, prognosis, and management" as well as "ureter trauma, diagnosis, prognosis, and management". A comprehensive and thorough approach was utilized following the PRISMA checklist and algorithm (see Fig. 1). Of the results generated from the search terms specified above, duplicates were removed and full-text articles published in English within the last thirty years were initially included. These resultant articles were then evaluated for content—articles, including literature reviews and case reports, containing information regarding human ureter and/or bladder injury cause, prognosis, diagnosis, and treatment were considered relevant and selected for categorization. From these resultant articles, only human studies reporting statistical Level I–IV evidence pertaining to the morbidity, mortality, treatment, diagnosis, and prognosis of ureter and/or bladder injury were chosen. Case reports and reviews of the literature were excluded. Using these specific selection criteria, the synthesized information resulted in a narrowed and selected reference list of 26 Level III and IV human studies.

Table 1 AAST OIS grades of injury to the bladder and ureter Adapted from Moore, et al. [5]

Grade	Injury type	Description of injury
Bladder Injury Scale		
I	Hematoma	Contusion, intramural hematoma
	Laceration	Partial thickness
II	Laceration	Extraperitoneal bladder wall laceration <2 cm
III	Laceration	Extraperitoneal (≥2 cm) or intraperitoneal (<2 cm) bladder wall laceration
IV	Laceration	Intraperitoneal bladder wall laceration ≥2 cm
V	Laceration	Intraperitoneal or extraperitoneal bladder wall laceration extending into the bladder neck or ureteral orifice (trigone)
Ureter Injury Scale		
I	Hematoma	Contusion or hematoma without devascularization
II	Laceration	<50% transection
III	Laceration	≥50% transection
IV	Laceration	Complete transection with <2 cm devascularization
V	Laceration	Avulsion with >2 cm devascularization

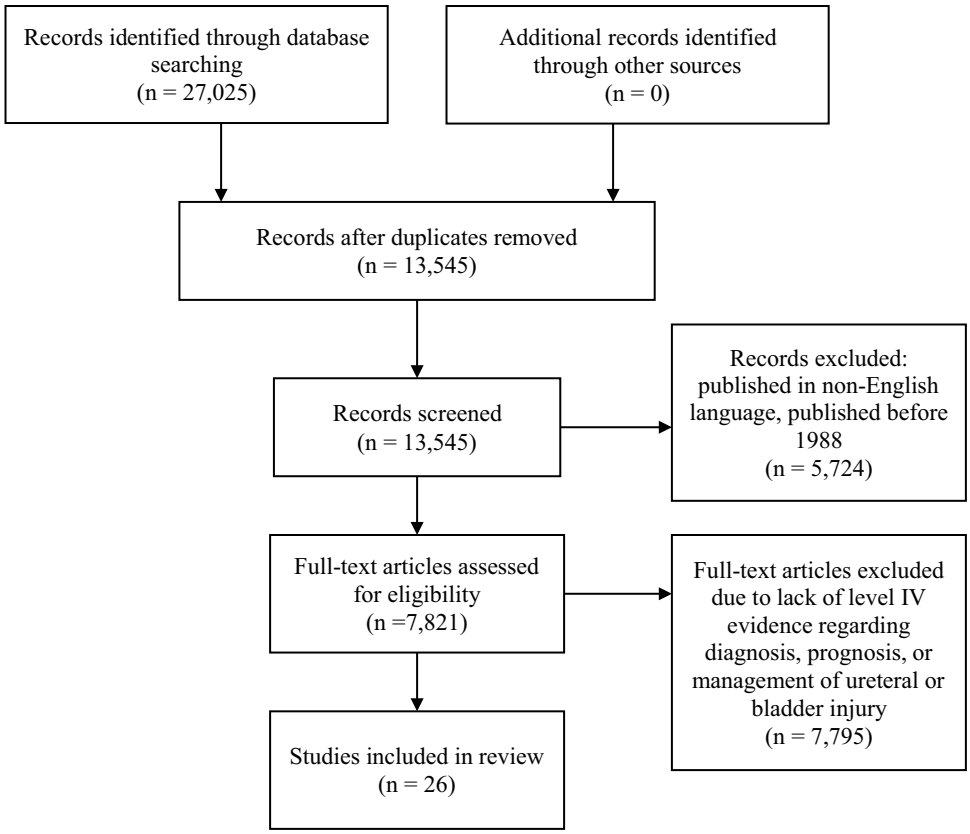

Fig. 1 PRISMA diagram

Results

The literature search yielded the following results for each term: "bladder trauma"—11,410 results, 54 relevant, 15 selected; "bladder trauma and diagnosis"—6404 results, 33 relevant, 0 selected; "bladder trauma and prognosis"—1517 results, 5 relevant, 0 selected; "bladder trauma and management"—2066 results, 8 relevant, 0 selected; "ureter trauma"—3042 results, 44 relevant, 10 selected; "ureter trauma and diagnosis"—1805 results, 15 relevant, 1 selected; "ureter trauma and prognosis"—257 results, 6 relevant, 0 selected; "ureter trauma and management"—524 results, 7 relevant, 0 selected. After duplicates were removed, a total of 13,545 studies remained. Subsequently, 172 of these articles were appropriate after screening of the title, abstract, and body. Of these, 26 studies contained Level III and IV data regarding mechanism or type of injury, management, and rates of mortality for human ureteral and/or bladder injuries (see Tables 2, 3). This tabulated list of references includes both retrospective and prospective Level III and IV studies with complete information that correlates the type of urologic injury with the most common mechanism of trauma and associated mortality rate.

We found that the majority of bladder ruptures were extraperitoneal, which occurred in 63% of cases (range 14–67%). Intraperitoneal bladder rupture occurred in 32% of cases (17–72%) and combined intra- and extraperitoneal bladder ruptures comprised the remaining cases (4.2% on average, range 0–20%). Mortality rates associated with bladder injury ranged from 0 to 34%, however, the average rate of mortality for all cases was 8% (see Table 2). Ureteral injuries occurred from penetrating mechanisms in 77% of cases (range 62–100%). An overwhelming majority of ureteral injuries required surgical management (96%) and the mortality rates for all ureteral injuries averaged 7% (range 0–25%).

Discussion

Trauma to the bladder

Two percent of all abdominal injuries that require surgical intervention involve the bladder [9]. Blunt trauma accounts for approximately 60–85% of these injuries while penetrating trauma accounts for 15–40% [6, 7]. Bladder injuries are graded by AAST organ injury scales (see Table 1) and defined as either contusion (grade I) or laceration, which may involve rupture (grades I–V) [3, 10]. Furthermore, rupture can be extraperitoneal (grade II, III, or V), intraperitoneal (grade III–V), or both depending on the nature

Table 2 Trauma to the Bladder, 1988–present [7, 11–21, 28, 29, 60]

Year	Author	*N*	Intraperitoneal rupture	Extraperitoneal rupture	I + E rupture	Conservative management	Operative management	Conservative mortality	Operative mortality	Total mortality
1988	Flancbaum	29	21 (72%)			0 (0%)	29 (100%)	0 (0%)	10 (34%)	10 (34%)
1990	Tan	36	11 (30.5%)	24 (66.7%)	1 (2.8%)	0 (0%)	36 (100%)	0 (0%)	6 (17%)	6 (17%)
1999	Madiba	120	94 (78.3%)	26 (21.7%)		26 (21.7%)	94 (78.3%)			17 (14%)
2002	Hsieh	51	21 (41.2%)	14 (27.5%)	10 (19.6%)	13 (25.5%)	38 (74.5%)	0 (0%)	0 (0%)	0 (0%)
2003	Parry	51	36 (70.6%)	15 (29.4%)						3 (5.9%)
2009	Petros	64				4 (6.25%)	60 (93.8%)			5 (8%)
2010	Salako	23	6 (26.1%)	5 (21.7%)	2 (8.7%)					1 (1%)
2012	Deibert	816	140 (17.2%)	676 (82.8%)	0 (0%)	482 (59.1%)	334 (40.9%)	37 (7.7%)	8 (2.4%)	45 (5.5%)
2013	Cinman	42				1 (2.4%)	41 (97.6%)			
2013	Matlock	54	27 (50%)	22 (40.7%)	5 (9.3%)	22 (40.7%)	32 (59.3%)			6 (11%)
2013	Pereira	111	51 (45.9%)	38 (34.2%)	22 (19.8%)	10 (9%)	101 (90.9%)	0 (0%)	12 (10.8%)	12 (10.8%)
2015	Bakal	10	4 (40%)	3 (30%)	3 (30%)	2 (20%)	8 (80%)			
2015	Zou	6	2 (33.3%)	4 (66.6%)	0 (0%)	0 (0%)	6 (100%)	0 (0%)	0 (0%)	0 (0%)
2016	Johnsen	161	60 (37.3%)	89 (55.3%)	12 (7.5%)	56 (34.8%)	42 (26%)			4 (2.5%)
2016	Osterberg	7	5 (71.4%)	1 (14.3%)		1 (14%)	6 (86%)			
	Total		478 (32.4%)	917 (63.4%)	55 (4.2%)	616 (40.8%)	827 (54.9%)			109 (7.7%)

Table 3 Trauma to the Ureter, 1988–present [18, 29, 36–46]

Year	Author	*N*	Penetrating	Blunt	Conservative management	Operative management	Total mortality
1988	Medina	20	19 (95%)	1 (5%)	0 (0%)	20 (100%)	5 (25%)
1991	Ozumba	48	48 (100%)	0 (0%)			1 (2.1%)
1992	Campbell	15	12 (80%)	3 (20%)			
1996	Velmahos	41	41 (100%)	0 (0%)			3 (7.3%)
2001	Perez	118	118 (100%)	0 (0%)	3 (2.5%)	115 (97.5%)	
2003	Elliot	36	32 (89%)	4 (11%)	2 (5.6%)	34 (94.4%)	
2005	Best	57	55 (97%)	2 (3%)			6 (10.5%)
2006	Kunkle	40	37 (93%)	3 (7%)	0 (0%)	40 (100%)	
2007	Fraga	20	20 (100%)	0 (0%)			0 (0%)
2010	Abid	20	20 (100%)	0 (0%)	2 (10%)	18 (90%)	
2010	Siram	582	358 (62%)	224 (38%)			41 (7.0%)
2013	Cinman	10	10 (100%)	0 (0%)	1 (10%)	9 (90%)	
2015	Zou	2	2 (100%)	0 (0%)	1 (50%)	1 (50%)	0 (0%)
	Total	1009	772 (76.5%)	237 (23.5%)	9 (3.7%)	237 (96.3%)	56 (7.3%)

and location of the injury [6]. Extraperitoneal bladder rupture is strongly associated with pelvic fractures while intraperitoneal rupture usually results from a blunt force directly applied to a full bladder [6]. Upon review of the literature, extraperitoneal, intraperitoneal, and combined intra- and extraperitoneal bladder rupture occurred in 63, 32, and 4% of bladder injuries, respectively (see Table 2) [7, 11–20]. A distended bladder has a higher risk of rupture than an empty one because it projects into the abdominal cavity away from its protective location in the pelvis. More specifically, the dome of the bladder is at highest risk of rupture owing to the weakened area around the urachal attachment [4, 6]. The bladder is also more vulnerable to injury in children due to their underdeveloped pelvic bones [6].

Historically, the most common etiologies of bladder injury involved penetrating mechanisms which were responsible for 60–85% of cases [6]. Recent literature suggests, however, that blunt mechanisms are now responsible for over 50% of bladder injuries [7]. Motor vehicle collisions (MVCs) are the most common blunt mechanism (47.3%) while abdominal gunshot wounds (GSWs) are the most frequent penetrating mechanism (87.3%) involved in bladder trauma [7]. Trauma to the bladder also occurs in association with sports injuries to the abdomen, which accounts for up to 10% of all bladder cases [6]. Bladder perforations frequently occur in association with other injuries, most commonly involving pelvic fractures (57.1%) and the bowel (23.3–89.2%). Isolated bladder injury is rare and typically occurs secondary to iatrogenic mechanisms [3, 21, 22]. Traumatic injury to the bladder may also occur from perineal impalement injuries—in fact, one study reported that 75% of females who suffered genital injury also presented with associated injuries to the bladder or other components of the renal system [23]. A recent study of male United States service members deployed to Iraq or Afghanistan reported that injury to the bladder may be sustained during combat [24]. However, due to the increased utilization of personal protection equipment, injury to the external genitalia (urethra, penis, scrotum, testes) was more frequently encountered (73.2%) than injury to the bladder (9.5%) [24].

Diagnosis of trauma to the bladder

Physical penetration, bruising, and tenderness from blunt impact to the suprapubic region may signal injury to the bladder [4]. Bladder injury commonly presents with an associated pelvic fracture at a frequency of 57.1% in blunt and 3.6% in penetrating traumas [6]. Bladder rupture typically presents with gross hematuria, lower abdominal pain, and either increased frequency or difficulty with urination [6]. Conversely, if a patient has sustained a pelvic fracture and only exhibits microscopic hematuria, there is less than 1% chance that the bladder has been injured according to the American Urological Association (AUA) Core Trauma Guidelines [25].

Imaging technology may be utilized to diagnose bladder injury; however, it is important to note that in cases of hemodynamic instability, imaging studies are not recommended, as the patient should undergo surgical exploration expediently [10]. Hemodynamically stable patients can be studied with CT urography, cystography, or cystourethrography [8, 10, 26]. According to the AUA, transurethral cystography is the mainstay for the diagnosis of bladder rupture in a trauma setting and must include three views (one with a scout, one with the bladder filled, and one

taken post-drainage) [25]. To accurately diagnose a bladder injury, the Foley catheter must be clamped during these studies [10]. The bladder needs to be fully distended, optimally to at least 350 ml, which is rarely achieved without retrograde filling. Bladder filling of less than 250 ml is considered inadequate and may result in a false negative study. A "drain-out" film is also recommended to complete the studies as up to 10% of all bladder injuries are identified only by these images. Both transurethral cystograms and CT cystograms are equally effective in diagnosing bladder injuries when properly performed. If the presence of bladder rupture is not evident on initial CT and existing associated injuries are convincing enough to warrant further investigation for bladder or urethral involvement (especially when an anterior pelvic ring fracture is present), then the use of a retrograde urethrogram is indicated [10, 27].

Management of trauma to the bladder

The extent and type of bladder injury are factors that must be taken into account when selecting treatment options. AAST-OIS grade I injuries (hematoma or partial thickness laceration) from blunt trauma generally do not require operative treatment (see Table 1) [8]. In contrast, grade II–V injuries may require immediate intervention as mortality rates of bladder rupture range from 10 to 22% [7]. Bladder rupture has been successfully managed with conservative measures (catheter drainage and/or observation) 38% of the time, while surgical management was required in 55% of cases (Table 2) [7, 11–14, 17–20, 28, 29]. Non-operative management of simple extraperitoneal bladder rupture with catheter drainage has been the standard of care for decades and is equally effective as operative repair in most patients. In patients undergoing surgical intervention for other injuries, cystorrhaphy decreases the risk for low- and high-grade urologic complications (70 vs. 42 and 30 vs. 4%, respectively), time in the intensive care unit (9.0 vs. 4.0 days), and overall hospital stay (18.9 vs. 10.6 days) [19]. If extraperitoneal urinary leaks are persistent, embolotherapy may be utilized to intentionally block the site of bladder rupture with a copolymer [27]. The AUA Core Trauma Guidelines also lists several absolute indications for surgical management of extraperitoneal bladder injuries, which include persistent hematuria, associated pelvic organ injury, the presence of bladder foreign bodies or projecting bone, ongoing urinary leak, and penetrating trauma [25]. Furthermore, the safest approach to repair an extraperitoneal bladder injury in a patient with concomitant pelvic fracture is through the bladder lumen via the creation of an anterior cystostomy, which allows for full visualization of the bladder lumen, thus, lessening the chance for massive bleeding.

Intraperitoneal rupture of the bladder is usually considered an absolute indication for surgical intervention; however, exploration of the deep pelvic retroperitoneum is not advised immediately following severe trauma, as the patient may exsanguinate from the pelvic venous plexus [20]. Additionally, if the intraperitoneal bladder injury in sustained in the context of a pelvic fracture, the intraperitoneal injury should be opened wide enough to confirm that other additional extraperitoneal injuries have not occurred [25]. Recently, hemodynamically stable patients with intraperitoneal bladder rupture have been successfully treated using a minimally invasive laparoscopic approach [30, 31]. Immediately following bladder repair, either methylene blue or indigo carmine can be insufflated through the Foley into the bladder to identify any significant leaks. Then a closed-suction drain is usually placed in the prevesical space of Retzius to drain any developing urinary leaks and prevent future urinoma formation. Cystograms should be obtained 7–14 days after primary bladder repairs to demonstrate any residual leaks; if none are found, the catheter can be removed. Optimally, the closed-suction drain is left in place until after the Foley catheter has been removed and the patient is voiding normally, in case of a delayed leak [32].

Since bladder injuries are, at times, associated with urethral injuries, approaches to management must address both injuries. For the extremely rare female urethral disruptions, treatment depends on the location of the injury; proximal and mid-urethral injuries require primary repair via respective retropubic and transvaginal approaches [32]. Given the close proximity of the bladder and uterus, these organs are often injured concomitantly. Pregnant patients may require suprapubic cystostomy if indwelling catheter drainage is insufficient [33]. Treatment of male anterior urethral injuries is dictated by mechanism of injury. Blunt injuries can be treated by early endoscopic realignment; however, this is not always easily achieved and may harm the urethra when multiple attempts are required. Otherwise, such an injury may be treated by suprapubic urinary diversion with a delayed urethroplasty at about three months post-injury. Penetrating urethral injuries may be managed by primary closure, anastomotic repair, or staged urethral marsupialization based on the severity of injury [32]. Overall, proper treatment of such injuries is necessary to minimize the risk for long-term urinary issues and sexual dysfunction [32].

Prognosis of trauma to the bladder

Mortality rates for bladder injury range from 0 to 34% with an average rate of 8% (see Table 2) [11–17, 19, 20, 28]. Factors that affect the prognosis of bladder injuries are related to patient status upon presentation to the hospital. Variables associated with increased mortality include the

presence of a pelvic fracture, systolic blood pressure less than 90 mmHg, Injury Severity Score (ISS) less than 25, and Revised Trauma Score (RTS) less than 7.84 (RTS is calculated using respiratory rate, Glasgow Coma Scale (GCS) score, and systolic blood pressure) [7]. Conversely, hemodynamically stable patients with a higher GCS and a normal respiratory rate have lower morbidity and mortality rates [7]. Females are less likely to sustain bladder injury than males, but are at higher risk for having an undiagnosed bladder injury [34]. An overlooked, untreated bladder injury may allow leakage of urine into the abdomen resulting in infection and increased rates of morbidity and mortality [19]. As mentioned above, extraperitoneal bladder rupture can be managed non-operatively which may lead to fewer associated complications than regimens involving a surgical approach [35]. Currently, a correlation between AAST-OIS bladder injury grade and mortality has not been described [7].

Trauma to the ureter

Similar to bladder trauma, ureteral injuries are graded by the AAST-OIS (see Table 3) [3]. Grade I injuries are contusions or hematomas without devascularization while grades II–V involve varying degrees of laceration from less than 50% transection to complete avulsion with devascularization. Ureteral injuries may also be further divided into three categories based on mechanism of injury: penetrating, blunt, and iatrogenic. For purpose of this review and according to standard PRISMA-based approaches, iatrogenic injury was categorized under penetrating due to the nature of these injuries. Penetrating ureteral injuries are more prevalent in the literature, occurring 77% of the time (most commonly due to gunshot and stab wounds). Conversely, blunt ureteral injuries occur less frequently and have been recorded in 23.5% of cases (see Table 3) [18, 29, 36–46]. Penetrating ureteral injuries are more common in young males, often located at the distal third of the ureter, and have an overall mortality rate of 6% [3, 47, 48]. Data regarding blunt ureteral trauma is lacking, given the rarity of such events.

Iatrogenic injury is the prevailing etiology reported for ureteral injuries, which is most commonly encountered in the setting of gynecological surgery [10, 33]. As laparoscopic surgical techniques are utilized to a greater extent, it is expected that the ureter will continually be at risk [27, 49, 50]. A 20-year retrospective study evaluating ureteral injury sustained during laparoscopic hysterectomy identified 41 ureteral injuries in 37 patients (4 with bilateral injury). The mean time to diagnosis was 29 days, which is concerning since time to diagnosis is an important prognostic factor for such injuries [33]. Additionally, ureteral injury is a known complication of pelvic surgery in both males and females, occurring 0.5–1.0% of the time [50].

Diagnosis of trauma to the ureter

Ureteral injury occurs in less than 1% of all urologic trauma [3, 22]. This low incidence is due to the protected location of the ureters by the bony pelvis, psoas muscles, and vertebral bodies [3]. However, there is a significant morbidity rate associated with ureteral injury in the context of multisystem trauma due to the likelihood of severe concomitant injuries. During a 10-year study, 20 ureteral injuries were associated with coexisting injuries involving the bowel (17), vascular structures (8), and other urologic trauma (4) [47]. Furthermore, there are no pathognomonic or classic signs and symptoms of ureteral injury, thus a high index of suspicion in the setting of penetrating abdominal trauma is necessary for prompt and appropriate intervention. When symptoms are identified, they often include hematuria, flank pain, ecchymosis, and hypotension, although hematuria itself may not always be present (documented in 44.4% of cases) [22].

A single imaging technique best suited to diagnose acute ureteral injury has not been identified. The AUA recommends intravenous contrast-enhanced abdominal/pelvic CT with 10-min delayed images (CT urogram) for accurate evaluation of the ureter [51]. Ureteral injury is suggested on CT by the presence of contrast extravasation, delayed pyelogram, hydronephrosis, and lack of contrast in the ureter distal to the site of suspected injury [3, 4, 52]. Focused assessment of sonography in trauma (FAST) is commonly used during initial evaluation, but is unable to properly diagnose ureteral injuries due to the anatomic location of the ureters and their relatively small size [22]. A single shot intravenous pyelogram (IVP) may intraoperatively provide anatomic and functional information regarding a ureteral injury. IVP, however, is an unreliable method for exclusion of ureteral injury and should only be utilized once hemodynamic stability has been achieved. For further anatomical delineation, a retrograde pyelogram can be considered and should be utilized when a delayed diagnosis of iatrogenic ureteral injury is suspected (due to the presence of urinoma, urinary fistula, and/or abscess formation) as it allows for simultaneous stent placement [3]. In hemodynamically unstable patients, ureteral injuries should be diagnosed through exploratory laparotomy, either by direct inspection or by visualizing extravasation of excreted intravenous dye, such as methylene blue or indigo carmine [3, 22].

Management of trauma to the ureter

Treatment of ureteral injuries depends on hemodynamic stability, site of injury, presence of associated injuries, and

Table 4 Levels of evidence. Adapted from Chung et al. [61]

Level of evidence	Description
I	High-quality randomized controlled trials
II	Lesser-quality randomized controlled trials
III	Retrospective comparative study; case control study; systematic review
IV	Case series
V	Expert Opinion or case report

Table 5 Bladder trauma and levels of evidence

Year	Author	*N*	Data collection	Level of evidence
2012	Deibert	816	Retrospective	III
1988	Flancbaum	29	Retrospective	IV
1990	Tan	36	Retrospective	IV
1999	Madiba	120	Retrospective	IV
2002	Hsieh	51	Retrospective	IV
2003	Parry	51	Retrospective	IV
2009	Petros	64	Retrospective	IV
2010	Salako	23	Retrospective	IV
2013	Cinman	42	Prospective	IV
2013	Matlock	54	Retrospective	IV
2013	Pereira	111	Prospective	IV
2015	Bakal	10	Retrospective	IV
2015	Zou	6	Retrospective	IV
2016	Johnsen	161	Retrospective	IV
2016	Osterberg	7	Prospective	IV

Table 6 Bladder trauma—synopsis of studies

Level of evidence	*N* (# of studies)	Data collection (*N*)
Level I	0 (0)	
Level II	0 (0)	
Level III	816 (1)	1 Retrospective (816)
Level IV	756 (14)	11 Retrospective (596) 3 Prospective (160)
Level V	0 (0)	
Total	1581 (15)	

Table 7 Ureteral trauma—levels of evidence

Year	Author	*N*	Data collection	Level of evidence
1988	Medina	20	Retrospective	IV
1991	Ozumba	48	Retrospective	IV
1992	Campbell	15	Retrospective	IV
1996	Velhamos	41	Retrospective	IV
2001	Perez	118	Retrospective	IV
2003	Elliot	36	Retrospective	IV
2005	Best	57	Retrospective	IV
2006	Kunkle	40	Retrospective	IV
2007	Fraga	20	Retrospective	IV
2010	Abid	20	Retrospective	IV
2010	Siram	582	Retrospective	IV
2013	Cinman	10	Prospective	IV
2015	Zou	2	Retrospective	IV
	Total	1009		

extent of devitalized ureter. In this review of the literature, ureteral injuries were managed conservatively 3.7% of the time while the remainder of cases (96.7%) required surgical intervention (Table 3) [18, 29, 36, 40, 41, 43, 45]. If the situation allows, working closely with a urologist to address ureteral damage may provide additional benefit to the patient, particularly with regards to long-term follow-up and overall continuity of care. The primary goal for the management of a ureteral injury is to maintain renal drainage. When injuries are identified early, surgical repair over a Double-J stent using fine absorbable suture, such as chromic or vicryl, may be successful, but a closed-suction drain should be placed in the retroperitoneal space to control any leakage (see Tables 4, 5, 6, 7).

When the patient is hemodynamically unstable and damage control is required, surgical repair of the ureteral injury may be delayed for 48–72 h to allow for the correction of hypotension, coagulopathy, and trauma-induced hypothermia. In this instance, a percutaneous nephrostomy tube or an externalized Foley catheter should be used to temporarily divert urine away from the site of injury until future repair of the ureter may safely take place [3]. In contrast, if the patient is hemodynamically stable, imaging studies should be obtained [22]. Retrograde pyelography may be utilized to reveal an underlying injury for which urinoma drainage and urinary diversion by stent or percutaneous nephrostomy are recommended [22]. In this setting, ureteral stents may facilitate healing but their usage remains controversial, as they have been associated with complications such as stricture formation, inflammatory reaction, and discomfort [3]. Therefore, clinical judgment should be exercised when selecting the appropriate course of treatment [3, 22]. Finally, if the above measures fail and issues persist, surgical exploration is indicated [22].

Blood supply to the ureters follows a segmental fashion from branches of the renal artery, aorta, and internal iliac artery. This pattern of distribution is important to consider when mobilizing and repairing the ureter to prevent ureteral devascularization [22]. The AUA suggests that when ureteral contusion or ischemia occurs as a result of injury induced by high-velocity projectiles, the injured portion of the ureter should immediately be resected or stented then

followed with close observation [51]. Simple lacerations should be repaired perpendicular to the ureteral axis to prevent stricture formation; however, formal reconstruction is required for large ureteral injuries [22]. Basic surgical reconstruction of large ureteral injuries includes a tension-free, water-tight anastomosis, debridement of devitalized tissues, spatulation of each end, isolation of the ureteral repair from associated injuries, and adequate retroperitoneal drainage via a closed-suction drain [3, 22]. Fibrin sealant, commonly used in urology, has been proven safe for use in the trauma setting and may reinforce ureteral anastomosis, although objective rates of efficacy are not reported in the literature [22]. Appendiceal-ureter, ileal-ureter conduits, or renal autotransplant may be considered for more extensive injuries or in cases of complete ureter loss [22]. Such reconstruction techniques are not ideal in the setting of acute multisystem trauma and should be utilized once the patient is stable.

Ureteral reconstruction depends on the location and length of injury. In rare cases, the patient may develop vesicoureteral reflux (VUR) following ureteral injury [53, 54]. VUR has been successfully treated with periureteral injection of proper medication, such as polyacrylate polyalcohol copolymers [54]. When severe injury to the upper ureters prevents proper ureteral function, nephrectomy may be considered. Laparoscopic nephrectomy with autotransplantation is an option in such cases where ureter trauma alters kidney viability, although this would be an unusual approach in the setting of acute multisystem trauma [55].

Iatrogenic ureteral injuries often go unrecognized until complications such as urinoma and fistula formation develop. In these cases, the AUA recommends use of a nephrostomy tube and/or stent to divert urine away until reconstruction may take place two to three months later [51]. However, if these injuries are identified within the first post-operative week, immediate repair may be considered. Specifically, endoscopic iatrogenic injuries may recover with the use of stenting alone [51].

Prognosis of trauma to the ureter

After careful review of published studies, mortality rates for ureteral injury range from 0 to 25% with an average of 7% (see Table 3) [18, 36, 37, 39, 42, 44, 46]. Ureteral injuries themselves are not usually life-threatening, but they often occur in the setting of severe multisystem trauma and, therefore, are associated with higher rates of mortality. The AAST grading of ureteral injuries may assist in determining outcome. In a series of 57 patients with ureteral injuries, Best reported injuries by AAST-OIS: grade I (5), grade II (8), grade III (13), grade IV (18), and grade V (13) with mortality rates of 0, 0, 15, 18, and 8%, respectively [42]. In Best's opinion, mortality resulted from associated injuries and was not directly related to the ureteral injury itself. However, there was a positive correlation between complexity of ureteral repair and injury grade.

Many ureteral injuries are left undiagnosed and only identified after complications such as urine leaks, urinoma formation, sepsis, periureteral abscess, ureteral fistula, and stricture development occur [56]. Renal failure may also result if ureteral injury is not managed appropriately [22]. Higher rates of morbidity and mortality have been correlated with delays in diagnosis; thus, proper and early diagnosis is necessary [22]. With appropriate stenting and placement of a nephrostomy tube, many complications can be prevented. Delayed complications, such as fistulas and strictures, may necessitate surgical repair [22]. In severe cases, a nephrectomy or even an auto-transplant may be required. As a general rule, kidneys with less than 20% function may not be worth extensive salvage surgery and are often best treated with a nephrectomy, especially if symptomatic.

Limitations

Limitations of this article are similar to all PRISMA-guided review articles: the dependence on previously published research and availability of references. In addition, there is a paucity of Level I and Level II evidence regarding this specific traumatic injury.

Conclusion

Bladder and ureteral injuries are rare and proper knowledge of diagnosis and treatment are essential for favorable prognoses. Bladder injuries may be caused by penetrating, blunt, or iatrogenic trauma, with GSW and MVC contributing to the majority of blunt and penetrating injuries, respectively. Upon hospital admission, prognostic factors for bladder injury include systolic blood pressure, respiratory rate, GCS, ISS, and the presence of pelvic fracture. AAST-OIS bladder injury grade has not been found to correlate with rates of mortality, but may be used to aid management decisions [7]. Management of minor bladder trauma with external drainage tends to be effective. Severe rupture may require further surgical intervention.

Ureteral injuries also occur by penetrating and blunt mechanisms, but iatrogenic mechanisms predominate. The main prognostic factor for ureter injury is time to diagnosis as renal failure may result when appropriate care is delayed. Unlike minor bladder injury, management of ureteral injury usually requires surgical reconstruction [22]. Outcomes following trauma to the bladder and

ureter improve when a high level of clinical suspicion is maintained and individualized approaches for each injury type are utilized.

This collective review of the literature is relevant and important given the potential harm of these injuries—both short and long-term. Most recently, an epidemiologic study of genitourinary injuries resulting from traffic accidents revealed that the bladder and ureter were involved in 10 and 1% of all MVCs, respectively [57]. Though genitourinary injuries most commonly involve the kidney, healthcare providers must be prepared to promptly recognize and initiate the appropriate treatment for ureteral and bladder injuries, as outcomes have been directly correlated with time to intervention. A recent study specific to iatrogenic post-hysterectomy ureteral injury further supports this claim, as patients who presented early (within the two week post-operative period) had higher success rates with endourological procedures, avoiding the need for open repair [58]. Though delayed diagnosis of ureteral injury should be avoided at all cost, prompt diagnosis is not always possible due to the nature of such injuries. It has recently been reported that retrograde stenting is an effective initial treatment in these cases where diagnosis of iatrogenic ureteral injury has been delayed [59]. Though genitourinary injury is relatively uncommon, the morbidity and mortality associated with such injuries is quite significant. The prognoses of ureteral and bladder injuries have been directly correlated with time to diagnosis thus current knowledge regarding appropriate treatment and intervention is a must in any healthcare setting.

Compliance with ethical standards

Conflict of interest B. Phillips, MD, S. Holzmer, BS, L. Turco, BS, M. Mirzaie, E. Mause, A. Mause, A. Person, MD, S.W. Leslie, MD FACS^{+}, D. L. Cornell, MD, M. Wagner, MD, FACS, R. Bertellotti, MD, and J. A. Asensio, MD, FACS, FCCM, FRCS (England), KM declare no conflict of interest.

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References

1. Gad MA, Saber A, Farrag S, Shams ME, Ellabban GM. Incidence, patterns, and factors predicting mortality of abdominal injuries in trauma patients. N Am J Med Sci. 2012;4(3):129–34.
2. Klimek PM, Lutz T, Stranzinger E, Zachariou Z, Kessler U, Berger S. Handlebar injuries in children. Pediatr Surg Int. 2013;29(3):269–73.
3. Bryk DJ, Zhao LC. Guideline of guidelines: a review of urological trauma guidelines. BJU Int. 2016;117(2):226–34.
4. Zaid UB, Bayne DB, Harris CR, Alwaal A, McAninch JW, Breyer BN. Penetrating trauma to the ureter, bladder, and urethra. Curr Trauma Rep. 2015;1(2):119–24.
5. Moore EE, Cogbill TH, Jurkovich GJ, et al. Organ injury scaling. III: chest wall, abdominal vascular, ureter, bladder, and urethra. J Trauma. 1992;33(3):337–9.
6. Guttmann I, Kerr HA. Blunt bladder injury. Clin Sports Med. 2013;32(2):239–46.
7. Pereira BM, de Campos CC, Calderan TR, Reis LO, Fraga GP. Bladder injuries after external trauma: 20 years experience report in a population-based cross-sectional view. World J Urol. 2013;31(4):913–7.
8. Marchand TD, Cuadra RH, Ricchiuti DJ. Laparoscopic repair of a traumatic bladder rupture. JSLS. 2012;16(1):155–8.
9. Carlin BI, Resnick MI. Indications and techniques for urologic evaluation of the trauma patient with suspected urologic injury. Semin Urol. 1995;13(1):9–24.
10. Obenauer S, Plothe KD, Ringert RH, Heuser M. Imaging of genitourinary trauma. Scand J Urol Nephrol. 2006;40(5):416–22.
11. Flancbaum L, Morgan AS, Fleisher M, Cox EF. Blunt bladder trauma: manifestation of severe injury. Urology. 1988;31(3):220–2.
12. Tan LB, Chiang CP, Huang CH, Chou YH, Wang CJ. Surgical treatment of the ruptured bladder: 22 years reviewed. J Formos Med Assoc. 1990;89(11):986–91.
13. Madiba TE, Haffejee AA. Causes and outcome of bladder injuries in durban. East Afr Med J. 1999;76(12):676–9.
14. Hsieh CH, Chen RJ, Fang JF, et al. Diagnosis and management of bladder injury by trauma surgeons. Am J Surg. 2002;184(2):143–7.
15. Parry NG, Rozycki GS, Feliciano DV, et al. Traumatic rupture of the urinary bladder: is the suprapubic tube necessary? J Trauma. 2003;54(3):431–6.
16. Salako AA, Adisa AO, Eziyi AK, Banjo OO, Badmus TA. Traumatic urologic injuries in ile-ife, nigeria. J Emerg Trauma Shock. 2010;3(4):311–3.
17. Matlock KA, Tyroch AH, Kronfol ZN, McLean SF, Pirela-Cruz MA. Blunt traumatic bladder rupture: a 10-year perspective. Am Surg. 2013;79(6):589–93.
18. Zou Q, Fu Q. Diagnosis and treatment of acute urogenital and genitalia tract traumas: 10-year clinical experience. Pak J Med Sci. 2015;31(4):925–9.
19. Johnsen NV, Young JB, Reynolds WS, et al. Evaluating the role of operative repair of extraperitoneal bladder rupture following blunt pelvic trauma. J Urol. 2016;195(3):661–5.
20. Deibert CM, Glassberg KI, Spencer BA. Repair of pediatric bladder rupture improves survival: results from the national trauma data bank. J Pediatr Surg. 2012;47(9):1677–81.
21. Bakal U, Sarac M, Tartar T, Ersoz F, Kazez A. Bladder perforations in children. Niger J Clin Pract. 2015;18(4):483–8.
22. Pereira BM, Ogilvie MP, Gomez-Rodriguez JC, et al. A review of ureteral injuries after external trauma. Scand J Trauma Resusc Emerg Med. 2010;18:6-7241-18-6.
23. Zhang C, Liu Q, Li BJ, et al. Penetrating injury of the vagina, bladder and omentum in a woman with 5 months gestation: case report and review of the literature. Int Urol Nephrol. 2014;46(6):1137–40.
24. Janak JC, Orman JA, Soderdahl DW, Hudak SJ. Epidemiology of genitourinary injuries among male U.S. service members deployed to iraq and afghanistan: early findings from the trauma

outcomes and urogenital health (TOUGH) project. J Urol. 2017;197(2):414–9.
25. AUA university core curriculum—bladder, urethra, genitalia trauma. https://www.auanet.org/university/core_topic.cfm?coreid=88. Accessed 2/1 2017.
26. Schaeffer AJ, Sood S, Logvinenko T, et al. Variation in the documentation of findings in pediatric voiding cystourethrogram. Pediatr Radiol. 2014;44(12):1548–56.
27. Radomski M, Messing J, Krishnasamy V, Akman A, Venbrux A, Sarani B. Successful percutaneous embolization of a persistent extraperitoneal bladder leak. Cardiovasc Intervent Radiol. 2014;37(3):852–4.
28. Petros FG, Santucci RA, Al-Saigh NK. The incidence, management, and outcome of penetrating bladder injuries in civilians resultant from armed conflict in Baghdad 2005–2006. Adv Urol. 2009;2009:275634.
29. Cinman NM, McAninch JW, Porten SP, et al. Gunshot wounds to the lower urinary tract: A single-institution experience. J Trauma Acute Care Surg. 2013;74(3):725–30 **(discussion 730–1)**.
30. Mortelmans D, Messaoudi N, Jaekers J, Bestman R, Pauli S, Van Cleemput M. Laparoscopic repair of intraperitoneal bladder rupture after blunt abdominal trauma. Urol J. 2014;11(1):1338–40.
31. Tsai CH, Wang YC, Wu SC, Hsieh CH. Laparoscopic repair of extraperitoneal urinary bladder rupture after blunt abdominal trauma. Am Surg. 2012;78(9):E385–6.
32. Lumen N, Kuehhas FE, Djakovic N, et al. Review of the current management of lower urinary tract injuries by the EAU trauma guidelines panel. Eur Urol. 2015;67(5):925–9.
33. Janssen PF, Brolmann HA, Huirne JA. Causes and prevention of laparoscopic ureter injuries: an analysis of 31 cases during laparoscopic hysterectomy in The Netherlands. Surg Endosc. 2013;27(3):946–56.
34. Delaney KM, Reddy SH, Dayama A, Stone ME Jr, Meltzer JA. Risk factors associated with bladder and urethral injuries in female children with pelvic fractures: an analysis of the national trauma data bank. J Trauma Acute Care Surg. 2016;80(3):472–6.
35. Morgan KA, Lancaster WP, Walters ML, et al. Enhanced recovery after surgery protocols are valuable in pancreas surgery patients. J Am Coll Surg. 2016;222(4):658–64.
36. Medina D, Lavery R, Ross SE, Livingston DH. Ureteral trauma: preoperative studies neither predict injury nor prevent missed injuries. J Am Coll Surg. 1998;186(6):641–4.
37. Ozumba BC, Attah CA. Ureteral injury in obstetric and gynecologic operations in nigeria. Int J Gynaecol Obstet. 1991;36(2):131–5.
38. Campbell EW Jr, Filderman PS, Jacobs SC. Ureteral injury due to blunt and penetrating trauma. Urology. 1992;40(3):216–20.
39. Velmahos GC, Degiannis E, Wells M, Souter I. Penetrating ureteral injuries: the impact of associated injuries on management. Am Surg. 1996;62(6):461–8.
40. Perez-Brayfield MR, Keane TE, Krishnan A, Lafontaine P, Feliciano DV, Clarke HS. Gunshot wounds to the ureter: a 40-year experience at Grady Memorial Hospital. J Urol. 2001;166(1):119–21.
41. Elliott SP, McAninch JW. Ureteral injuries from external violence: the 25-year experience at San Francisco General Hospital. J Urol. 2003;170(4 Pt 1):1213–6.
42. Best CD, Petrone P, Buscarini M, et al. Traumatic ureteral injuries: a single institution experience validating the american association for the surgery of trauma-organ injury scale grading scale. J Urol. 2005;173(4):1202–5.
43. Kunkle DA, Kansas BT, Pathak A, Goldberg AJ, Mydlo JH. Delayed diagnosis of traumatic ureteral injuries. J Urol. 2006;176(6 Pt 1):2503–7.
44. Fraga GP, Borges GM, Mantovani M, Ferreira U, Laurito TL, Netto NR Jr. Penetrating ureteral trauma. Int Braz J Urol. 2007;33(2):142–8 **(discussion 149–50)**.
45. Abid AF, Hashem HL. Ureteral injuries from gunshots and shells of explosive devices. Urol Ann. 2010;2(1):17–20.
46. Siram SM, Gerald SZ, Greene WR, et al. Ureteral trauma: patterns and mechanisms of injury of an uncommon condition. Am J Surg. 2010;199(4):566–70.
47. Palmer LS, Rosenbaum RR, Gershbaum MD, Kreutzer ER. Penetrating ureteral trauma at an urban trauma center: 10-year experience. Urology. 1999;54(1):34–6.
48. Morgan DE, Nallamala LK, Kenney PJ, Mayo MS. Rue LW,3rd. CT cystography: radiographic and clinical predictors of bladder rupture. AJR. 2000;174(1):89–95.
49. Parpala-Sparman T, Paananen I, Santala M, Ohtonen P, Hellstrom P. Increasing numbers of ureteric injuries after the introduction of laparoscopic surgery. Scand J Urol Nephrol. 2008;42(5):422–7.
50. Yuvaraja TB, Wuntakal R, Maheshwari A, Kerkar RA, Tongaonkar HB. Management and long-term follow-up of ureteric injuries during radical hysterectomy: single center experience. J Gynecol Surg. 2003;19(3):133–9.
51. AUA university core curriculum—renal, ureter trauma. https://www.auanet.org/university/core_topic.cfm?coreid=87. Accessed 2/1 2017.
52. Gomez RG, Ceballos L, Coburn M, et al. Consensus statement on bladder injuries. BJU Int. 2004;94(1):27–32.
53. Sung J, Skoog S. Surgical management of vesicoureteral reflux in children. Pediatr Nephrol. 2012;27(4):551–61.
54. Asgari SA, Asl AS, Safarinejad MR, Ghanaei MM. High success rate with new modified endoscopic treatment for high-grade VUR: a pilot study with preliminary report. J Pediatr Urol. 2016;12(2):100.e1–4.
55. Meng MV, Freise CE, Stoller ML. Expanded experience with laparoscopic nephrectomy and autotransplantation for severe ureteral injury. J Urol. 2003;169(4):1363–7.
56. 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(1):151–5.
57. Terrier JE, Paparel P, Gadegbeku B, Ruffion A, Jenkins LC, N'Diaye A. Genitourinary injuries following traffic accidents: analysis of a registry of 162,690 victims. J Trauma Acute Care Surg. 2017;82(6):1087–1093.
58. Patil SB, Guru N, Kundargi VS, Patil BS, Patil N, Ranka K. Posthysterectomy ureteric injuries: presentation and outcome of management. Urol Ann. 2017;9(1):4–8.
59. Chung D, Briggs J, Turney BW, Tapping CR. Management of iatrogenic ureteric injury with retrograde ureteric stenting: an analysis of factors affecting technical success and long-term outcome. Acta Radiol. 2017;58(2):170–5.
60. Osterberg EC, Awad MA, Gaither TW, et al. Major genitourinary-related bicycle trauma: results from 20 years at a level-1 trauma center. Injury. 2017;48(1):153–7.
61. Chung KC, Swanson JA, Schmitz D, Sullivan D, Rohrich RJ. Introducing evidence-based medicine to plastic and reconstructive surgery. Plast Reconstr Surg. 2009;123(4):1385–9.