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Diagnosis and Classification of Urethral Injuries

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Urethral injuries arise from a variety of different insults, ranging from external violence to urethral instrumentation. Most result from blunt trauma, with penetrating injuries more commonly reported in the military setting [1]. The male urethra is anatomically subdivided into anterior and posterior segments at the level of the urogenital diaphragm, and mechanism of urethral injury may also be subclassified along these lines. Posterior urethral injury usually occurs in close proximity to the external (ie, voluntary) urethral sphincter mechanism, and is usually initiated by a massive shearing force that results in pelvic fracture and disruption through the membranous urethra [2]. Membranous urethral disruptions are associated with multiple organ injury, whereas anterior urethral injuries usually occur in isolation. Examples of anterior urethral injuries include straddle trauma crushing the immobile bulbous urethra against the pubic rami, or a rupture of the corporal bodies (eg, penile fracture), leading to a laceration through the adjacent urethra. Iatrogenic injuries affect both anterior and posterior segments of the urethra, and are increasingly frequent, possibly because of increasing numbers of transurethral procedures and radical prostatectomies.

A sound diagnostic acumen in dealing with urethral injuries includes a high index of suspicion, with avoidance of urethral catheter passage until a potential urethral injury has been excluded. Certain clinical signs and symptoms will point the clinician toward a possible urethral injury, with a properly performed radiographic study confirming the diagnosis. Once the presence of a urethral injury has been diagnosed, the injury may be subclassified according to well-defined radiographic findings. These findings, as well as the overall condition of the patient, will in turn guide judicious initial management of the injured urethra.

This article concentrates on reviewing the major etiologies and mechanisms of urethral injury. For purposes of convenience and clarity, posterior and anterior urethral injuries due to external trauma are presented separately. The article discusses both clinical diagnostic findings and radiographic studies for each type of injury, and reviews the classification systems commonly used in urethral trauma. Iatrogenic urethral injuries, which may affect both anterior and posterior urethra, are reviewed separately. Female urethral injuries are also discussed. Timely and accurate diagnosis of urethral injuries leads to appropriate acute management and reduces long-term morbidity.

Anatomy

Understanding urethral injuries begins with a detailed comprehension of urethral anatomy. The adult male urethra is approximately 18 cm long, with the posterior urethra comprising the proximal 3 cm, and the anterior urethra comprising the remaining 15 cm, with the division point

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between the two located at the perineal membrane. The urethra may be further subdivided into five segments (Fig. 1):

Posterior urethra:
- Prostatic urethra
- Membranous urethra

Anterior urethra:
- Bulbous urethra
- Pendulous urethra
- Fossa navicularis [3]

The posterior urethra begins as the prostatic urethra at the level of the bladder neck and extends as a channel through the prostate, anterior to the midline. The bladder neck (ie, internal) sphincter extends from the internal meatus through the prostatic urethra to the level of the verumontanum. This sphincter is comprised most proximally of circular fibers of smooth muscle, which provide passive continence via tonic sympathetic fiber activity.

The prostatic urethra ends distal to the verumontanum, which is a 0.5 cm long protuberance found on the ventral wall of the urethra. The paired ejaculatory ducts empty into the prostatic urethra at the level of the verumontanum. The prostate itself is located deep within the pelvis, and is closely adherent to the posterior aspect of the anterior pubic arch at the level of the paired puboprostatic ligaments.

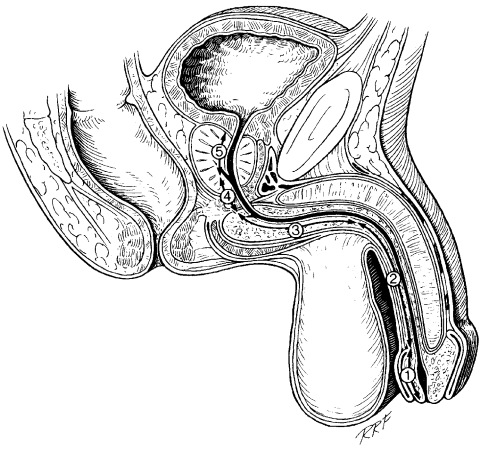

Fig. 1. Cross section of the male pelvis with the five urethral segments labeled. (*1*) Fossa navicularis. (*2*) Pendulous urethra. (*3*) Bulbous urethra. (*4*) Membranous urethra. (*5*) Prostatic urethra. (*From* Jordan GH, Schellhammer PF. Urethral surgery and stricture disease. In: Droller M, editor. Surgical management of urologic disease. St. Louis (MO): Mosby-Yearbook; 1992. p. 394.)

The membranous urethra is approximately 1 to 1.5 cm long, extending between the prostatic apex and the proximal corpus spongiosum. The membranous urethra is the only segment of the urethra that is unprotected by surrounding spongy tissue or prostatic stroma, and is thus more susceptible to external trauma. The distal sphincter mechanism is a combined voluntary and involuntary unit, with an outer layer of striated muscle fibers and an inner layer of smooth muscle intrinsic to the urethral wall [4]. The distal sphincter mechanism is typically about 2 cm long, but only 3 to 5 mm thick. Supporting the distal sphincter mechanism is an extrinsic periurethral striated muscle, which is under voluntary control. Contrary to early descriptions, the urogenital diaphragm does not completely encircle the membranous urethra, but rather forms an incomplete sling that offers posterior and lateral support. While each sphincteric unit may independently maintain passive continence once its confrere has been injured, the striated periurethral muscle may only assist with active continence (eg, interruption of voiding).

The bulbous urethra commences proximally at the level of the inferior aspect of the urogenital diaphragm, where it pierces and courses through the corpus spongiosum. The corpus spongiosum is a highly vascular network of elastic and smooth muscle fibers. A fibrous capsule known as the tunica albuginea surrounds the corpus spongiosum. The corpus spongiosum and the corpora cavernosa are in turn enclosed by two successive fascial layers. These layers are Buck's fascia and dartos fascia. Buck's fascia is the denser of the two layers, and is itself composed of an inner and outer lamina. The two laminae of Buck's fascia split to enclose the corpus spongiosum. The dartos fascia is a loose subdermal connective tissue layer that is continuous with the Colles' fascia in the perineum.

The urethral lumen remains eccentrically dorsally positioned in the corpus spongiosum throughout the bulbous urethra, but is centrally located in the pendulous urethra. The bulbous urethra is by definition enclosed not only by the corpus spongiosum, but also by the midline fusion of the ischiocavernosus (ie, bulbospongiosus) musculature. The bulbospongiosus muscle terminates just proximal to the penoscrotal junction, where the urethra continues distally as the pendulous urethra. The pendulous urethra is closely adherent to the corporal bodies dorsally. The

distal most portion of the anterior urethra is the fossa navicularis, which is surrounded by the spongy tissue of the glans penis.

The adult female urethra is approximately 4 cm long, and extends from the urethrovesical junction at the bladder neck to the vaginal vestibule. Two layers of smooth muscle that extend distally from the bladder neck encircle the proximal part of the urethra. The inner layer is circular, whereas the outer layer runs longitudinally. The smooth muscle is further surrounded by a striated muscle layer (ie, rhabdosphincter), which is thickest at the level of the mid-urethra, and relatively deficient at its posterior aspect (Fig. 2) [4].

Traumatic posterior urethral injuries

Etiology

Blunt trauma causes the vast majority of injuries to the posterior urethra. Historically, many of these injuries were associated with industrial or mining accidents [5]. However, improvements in industrial safety and the rise of the automobile have shifted the etiology of these injuries, leading to a decline in such injuries related to industrial accidents and a rise in injuries related to motor-vehicle mishaps. Urethral disruption occurs in approximately 10% of pelvic fractures, but almost all membranous urethral disruptions related to blunt trauma have an associated pelvic fracture [6]. The pelvic fractures that lead to urethral disruption are usually secondary to motor-vehicle accidents (68%–84%) or falls from heights and pelvic crush injuries (6%–25%) [7]. Pedestrians are far more at risk than passengers of suffering pelvic-fracture urethral-disruption injuries in motor-vehicle accidents. Other unusual causes of pelvic fracture and membranous urethral injury include horse kicks to the perineum [8] and injuries related to mechanical bulls (ie, the "urban cowboy" syndrome) [9].

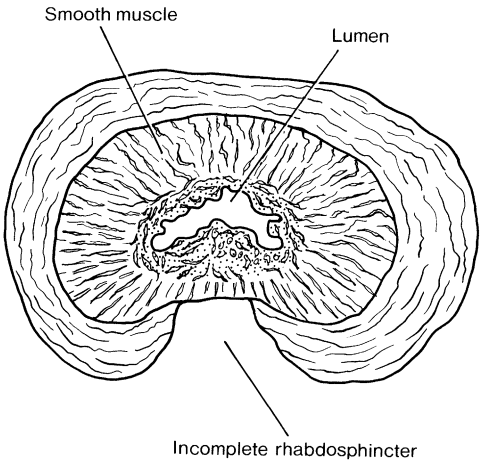

Fig. 2. The female urethra as seen in cross section. The rhabdosphincter is incomplete posteriorly. (*From* MacDiarmid SA, Chapple CR. Surgical management of injuries to the bladder neck. In: McAninch JW, editor. Traumatic and reconstructive urology. Philadelphia: W.B. Saunders; 1996. p. 539.)

Pelvic fractures occur predominantly in the first three decades of life, with a male/female ratio of 2:1 in young adults [10]. Furthermore, urethral injuries associated with pelvic fractures are much less common in females [11]. Some authorities have postulated that the female urethra is at a lower risk of injury because of its shorter length and its greater mobility in relation to the pubic arch [12]. Although pelvic fracture urethral injuries are rare in females overall, they predominate in the prepubertal and pubescent age groups. This tendency is likely because younger females have thinner and less mobile urethral tissues, and have compressible pelvic bones [13].

Because the forces causing pelvic crush injury leading to urethral disruption may be extreme, nonurologic injuries are frequently associated with pelvic fractures. In fact, such injuries are far more frequent than urethral injuries. These nonurologic injuries, including head or spinal-cord trauma, respiratory and musculoskeletal injuries, take precedence in the initial resuscitation of the multiply injured trauma victim [10]. Bladder rupture occurs in approximately 5% to 10% of pelvic fractures. With an associated urethral injury, the rate increases to 10% to 20% [14]. This associated urethral injury is most commonly an extraperitoneal rupture (56%–78%), but may be an intraperitoneal rupture (17%–39%), and least commonly a combined intra- and extraperitoneal rupture [15]. Concomitant injury to the bladder neck may have particularly devastating consequences in terms of continence. Because of the high association of urethral disruption with bladder rupture, all such patients require cystography to investigate this possibility. Prepubertal males are more likely to suffer extension of the disruption up into and through the prostatic urethra. This increased vulnerability to such injury is likely because the prostate is smaller and less protective at that age [8].

Female urethral injuries frequently have associated vaginal lacerations and concomitant rectal tears. In his recent series of pelvic-fracture-related injuries of the female urethra, Mundy reported a 75% incidence of vaginal injury and a 33% incidence of rectal injury [16].

Pelvic fractures: subtypes and risk stratification

Pelvic fractures may be classified according to the direction of the major force of injury, including lateral compression, anteroposterior compression, and vertical shear injuries [17]. In 1987, Young and Burgess first described this classification, which has been useful for orthopedic surgeons for prognosticating blood loss, deformity reduction, and fixation, among other variables [18]. Anteroposterior compression injuries are associated with an increased incidence of abdominal visceral and pelvic vascular injuries. These injuries open the pelvis and major morbidity results from pelvic bleeding. Lateral compression injuries, which close the pelvis, account for the largest number of associated injuries and complications of pelvic fractures [19]. Vertical shear injuries usually result from falls from great heights or from posterior forces applied to a fixed pelvis. These fractures cause disruption of both the anterior and posterior pelvic complexes, with the fractured hemipelvis moving separately from the opposite side. Pelvic fractures may also be classified as clinically stable or unstable. Vertical shear injuries are grossly unstable, while anteroposterior and lateral compression injuries are more commonly stable [18].

For the purposes of the urologist suspicious of urethral injury, certain pelvic fracture subtypes have a higher association with urethral disruption [20]. These subtypes include straddle fractures, which are also called butterfly fractures, where all four pubic rami are fractured. Another subtype is the Malgaigne fracture, involving disruption through ischiopubic rami anteriorly as well as through the sacrum or sacroiliac joint posteriorly. In a prospective study assessing the risk ratio of pelvic fracture subtype to membranous urethral injury, Koraitim found the highest risk for straddle fracture, with an odds ratio of 3.85, and Malgaigne fracture, with an odds ratio of 3.40 [7]. If a straddle fracture is combined with a sacroiliac joint diastasis, the odds ratio increases to 24.02 [7]. Conversely, the risk of urethral injury in fractures not involving the ischiopubic rami is negligible.

Pelvic fractures may thus be classified as low or high risk in terms of associated urethral disruption. The information obtained from initial pelvic radiography should be combined with clinical data in evaluating urethral injuries. In a recent retrospective study of 43 patients with lower urologic injuries in the context of pelvic fractures, Ziran found 10 patients whose injuries were missed at the initial evaluation [21]. Three patients in this series had missed urethral disruptions, which were ultimately discovered at the time of urgent exploratory laparotomy. All 3 patients in this subgroup had no clinical findings suggestive of urethral disruption (ie, no blood at the meatus and normal digital rectal exam). Nonetheless, all 3 patients had pelvic fractures at high risk for urethral disruption (ie, 2 had straddle plus sacral ala fracture, and 1 had a Malgaigne fracture). Radiographic findings on the initial anteroposterior pelvic film may thus rarely be the only clues suggesting urethral injury.

Mechanism of injury

The traditional concept of the mechanism of prostatomembranous urethral disruption involves a shearing force that avulses the apex of the prostate from the membranous urethra [22], where the membranous urethra is fixed in place by the urogenital diaphragm. Because the initial injury lacerates through the distal sphincter mechanism at the level of the membranous urethra, any future continence depends upon a competent bladder neck sphincter [23]. Pokorny postulated three mechanisms through which this shearing may occur [24]. The first involves upward displacement of one hemipelvis and symphysis (eg, in a Malgaigne fracture), with laceration into the urethra. The second mechanism includes straddle fractures whereby a free floating central symphyseal fragment is displaced posteriorly, leading to disruption. The third mechanism involves pubic symphysis diastasis, whereby the membranous urethra is stretched until it ruptures.

However, this traditional mechanism of injury has recently been called into question [25]. A number of studies have undermined this view, including Mundy's recent work, which attempted to prospectively study distal urethral sphincter function following anastomotic repair of a pelvic-fracture urethral-disruption defect [26]. Most the 20 subjects in this study showed endoscopic and urodynamic evidence of distal sphincter function. Although this study provides indirect evidence of

distal sphincter function and injury distal to the external sphincter, more convincing direct anatomic support for this view has come from a recent cadaveric study by Mouraviev and Santucci [27]. In this dissection study of victims who died with known pelvic-fracture urethral-disruption injuries, seven out of 10 subjects were found to have disruption distal to the external urinary sphincter. This evidence suggests that urethral disruption more likely represents partial or complete avulsion of the membranous urethra off the fixed bulbous urethra at the bulbomembranous junction.

Diagnosis of posterior urethral injury: clinical aspects

The possibility of posterior urethral injury should be suspected in the presence of a suspected or confirmed pelvic fracture. As noted previously, certain pelvic fracture subtypes are more likely associated with urethral disruption. Blood at the meatus is a cardinal sign of posterior urethral injury, and is seen in 37% to 93% of cases [28]. However, the amount of blood at the meatus does not appear to correlate with the severity of the injury [29]. A palpably distended bladder or inability to void, perineal bruising, and perineal ecchymosis are all suggestive of urethral disruption [30]. Digital rectal exam may disclose an elevated or displaced prostate gland in 34% of cases [31], but may be impalpable secondary to the significant hematoma that surrounds the prostate in the setting of pelvic fracture. Digital rectal exam may also disclose blood on the examining finger, which is highly suggestive of a rectal injury [6]. The triad of pelvic fracture, blood at the meatus, and inability to void are diagnostic of prostatomembranous urethral disruption [32].

Before the advent of widespread retrograde urethrography, unsuccessful catheterization attempts in pelvic-fracture patients were considered diagnostic of urethral disruption. Today, in the era of urethrography, the practice of attempting to catheterize pelvic-fracture patients should be condemned. However, the practice continues. A recent study of patients with suspected urethral disruption found 11 of 57 (19.3%) patients with catheters placed outside the bladder before arrival at the emergency room [33].

Unfortunately, none of the clinical findings listed above is entirely reliable in diagnosing a urethral disruption. Most urologists have argued that urethral catheterization attempts in the presence of the findings discussed above are contraindicated before diagnostic retrograde urethrography [32]. Those who support this argument cite the possibility of infecting the pelvic hematoma, as well as potentially converting a partial urethral rupture to a complete tear [34]. They also argue that such catheterization will result in inadequate staging of the injury. Others familiar with such issues argue that a single gentle attempt at catheterization is unlikely to create permanent damage. They also point out that, if the catheterization is unsuccessful, the attempt can be immediately followed by retrograde urethrography [10]. Urologists have debated this controversial point for several decades. All urologists would agree that the diagnostic study of choice is retrograde urethrography, and the threshold for performing it in the setting of suspected urethral injury should be low. Occasionally, a critically injured and unstable patient may require urgent bladder drainage before retrograde urethrography. In this case, the most prudent and expedient approach is to insert a percutaneous suprapubic catheter and evaluate the urethra once the patient is more stable [35].

Diagnosis of posterior urethral injury: radiographic aspects

Retrograde urethrography has become the study of choice in diagnosing urethral injuries. It is accurate, simple, and may be performed rapidly in the trauma setting [36]. While CT scanning is ideal for imaging upper urinary tract and bladder injuries, it has a limited role in the diagnosis of urethral injuries [37]. Nonetheless, a recent retrospective radiographic comparison of CT findings in patients with urethrographically proven urethral injuries revisited this issue [38]. Ali demonstrated CT findings of prostatic apex elevation and contrast extravasation above or below the urogenital diaphragm in various subclasses of urethral injury. While MRI is useful for imaging the posttraumatic pelvis before reconstruction [39], this modality has no role in urethral imaging in the trauma setting. Similarly, urethral ultrasound has limited diagnostic use in the acute setting. Ultrasonography may be useful in localizing the pelvic hematoma and bladder for planned suprapubic catheter placement.

Retrograde urethrography begins with proper patient positioning on the x-ray table. The patient should be supine with the pelvis elevated to 30° to 45° oblique to the horizontal plane. The thigh

closest to the table is flexed 90°, whereas the upper thigh is kept straight. This position allows clear visualization of the entire urethra, and should prevent the pelvic bones from obscuring any extravasation (Fig. 3). A scout film should be obtained to confirm correct positioning before urethrography. Oblique positioning may be limited by discomfort related to pelvic fractures.

The simplest technique of urethrography involves insertion of a 60 cc catheter tip syringe into the meatus for contrast injection. However, this method is discouraged because it results in unnecessary radiation of the operator's hand. Ideally, a 14 Fr Foley catheter is inserted into the fossa navicularis with the balloon inflated to 2 cc to seat the tip and prevent contrast from refluxing out the meatus. The catheter is then connected to a 60 cc catheter tip syringe filled with water-soluble undiluted contrast material. Then 30 cc of contrast material is injected retrograde into the urethra, with a single radiograph exposure taken toward the end of injection. This method permits adequate distension of the urethra, and should permit visualization of any extravasated contrast material. Fluoroscopic guidance during the study is ideal but is not absolutely necessary for diagnostic purposes.

In a retrograde urethrogram of an uninjured urethra, a smooth and continuous contour will be seen through the bulbous urethra. The contour typically cones down at the bulbomembranous junction. The normal prostatic urethra appears as a narrow passage with visible indentation by the verumontanum. An adequate retrograde urethrogram includes a jet of contrast passing through the bladder neck into the bladder (Fig. 4). Abnormalities on urethrography are readily identified and may be classified as outlined in the following section.

Classification of posterior urethral injuries

The most common classification system currently in use for blunt posterior urethral injuries was described by Colapinto and McCallum in 1977 [29]. Goldman and colleagues recently modified the system to include all common types of blunt urethral injuries [40]. This classification uses radiographic findings to sort blunt urethral injuries by type:

Type 1: Rupture of the puboprostatic ligaments and surrounding periprostatic hematoma stretch the membranous urethra without rupture (Fig. 5A).

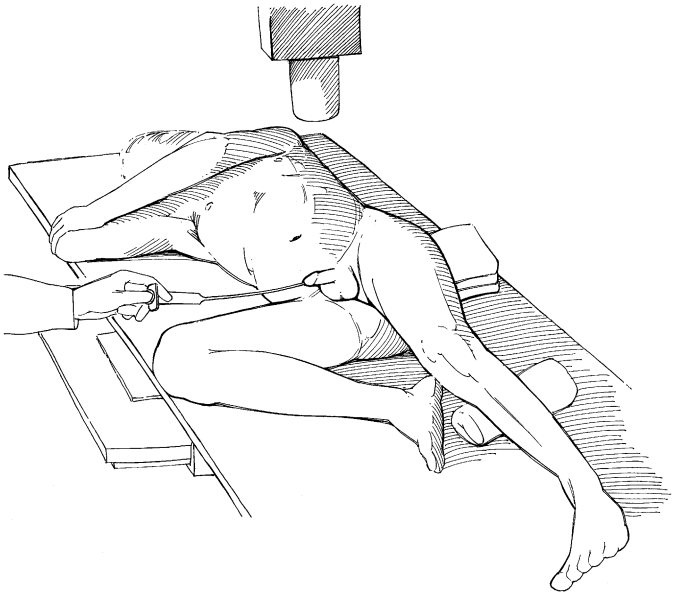

Fig. 3. Correct positioning for retrograde urethrography. The angle of the pelvis is oblique. The examiner's hand is kept away from the x-ray beam. (*From* Armenakas NA, McAninch JW. Acute anterior urethral injuries: diagnosis and initial management. In: McAninch JW, editor. Traumatic and reconstructive urology. Philadelphia: W.B. Saunders; 1996. p. 547).

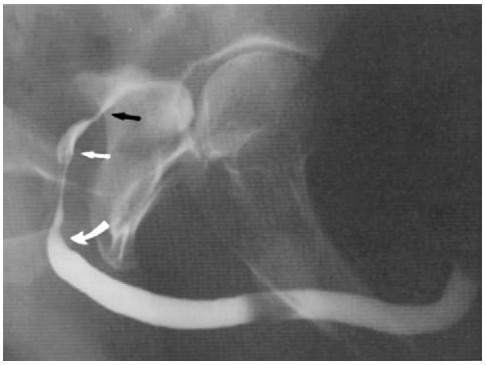

Fig. 4. A normal retrograde urethrogram. The anterior urethra has a smooth contour. Curved arrow shows where the normal bulbous urethra terminates at the cone-shaped bulbomembranous junction. The straight white arrow shows the verumontanum within the prostatic urethra. Contrast may be seen emanating into the bladder through the bladder neck at the level of the black arrow. (*From* Rosen MA, McAninch JW. Preoperative staging of the anterior urethral stricture. In: McAninch JW, editor. Traumatic and reconstructive urology. Philadelphia: W.B. Saunders; 1996. p. 552.)

Type 2: Partial or complete rupture of the membranous urethra above the urogenital diaphragm or perineal membrane. On urethrography, contrast material is seen extravasating above the perineal membrane into the pelvis (Fig. 5B).

Type 3: Partial or complete rupture of the membranous urethra with disruption of the urogenital diaphragm. Contrast extravasates both into the pelvis and out into the perineum (Fig. 5C).

Type 4: Bladder neck injury with extension into the urethra.

Type 4a: Extraperitoneal bladder rupture at the bladder base with periurethral extravasation, simulating a Type 4 injury.

Type 5: Pure anterior urethral injury.

Type 1 and 2 injuries are uncommon, each representing approximately 10% to 15% of posterior urethral injuries [41]. Either Type 2 or Type 3 injuries may be classified as complete or partial ruptures. The relative incidence of complete to partial tears is approximately 3:1 [20]. This radiographic distinction is clinically significant because partial tears may heal without significant stricture formation, whereas complete tears rarely do. Type 3 injuries are the most frequent, occurring in 66% to 85% of all cases [20]. Type 4 injuries are rare, but may have potentially dire consequences in terms of continence if they go unrecognized. Using radiographic appearance alone to distinguish Type 4 from Type 4a injuries may be difficult.

Another classification system for pelvic-fracture urethral injuries was recently introduced by Al Rifaei [42]. This classification system adds subcategories for proximal prostatic avulsion and attempts to distinguish injuries based upon evaluation of the sphincteric mechanism. This classification system has not yet been widely accepted.

Traumatic anterior urethral injury

Etiology and mechanism

Blunt or penetrating trauma may cause anterior urethral injuries. Blunt injuries are more commonly diagnosed, and the bulbous urethra is the most frequently injured segment (85%) [43] because it is fixed beneath the pubic bone, unlike the freely mobile pendulous urethra. Blunt injuries to the bulbous urethra are typically caused by straddle type injuries (eg, motor-vehicle accidents; bicycle accidents; falling astride onto a fence, railing or saddle) or kicks to the perineum. The force contacting the perineum crushes the bulbous urethra up against the inferior pubic rami, leading to contusion or urethral laceration [44] (Fig. 6).

Unlike prostatomembranous urethral disruptions, blunt anterior urethral trauma rarely has significant associated organ trauma. In fact, the straddle injury may be mild enough that the patient seeks no treatment at the time of the acute event. These patients typically present with bulbar urethral strictures after an interval of months to years [45]. In the recent review of straddle injuries to the bulbar urethra by Park and McAninch, 47 of 78 patients (60%) presented 6 months to 10 years after the acute injury with obstructive voiding symptoms or frank urinary retention [46].

Traumatic anterior urethral disruptions may also be related to penile fracture in 10% to 20% of cases. The mechanism of injury is typically a direct blow or buckling force applied to the erect penis during intercourse, with the erect penis striking the female pubic ramus. This force tears the tunica albuginea and leads to rapid detumescence and pain.

If the tear in the tunica extends into the corpus spongiosum, a urethral injury may result. Most patients are able to urinate normally following penile fracture, but the urologist must maintain a high index of suspicion for urethral injury.

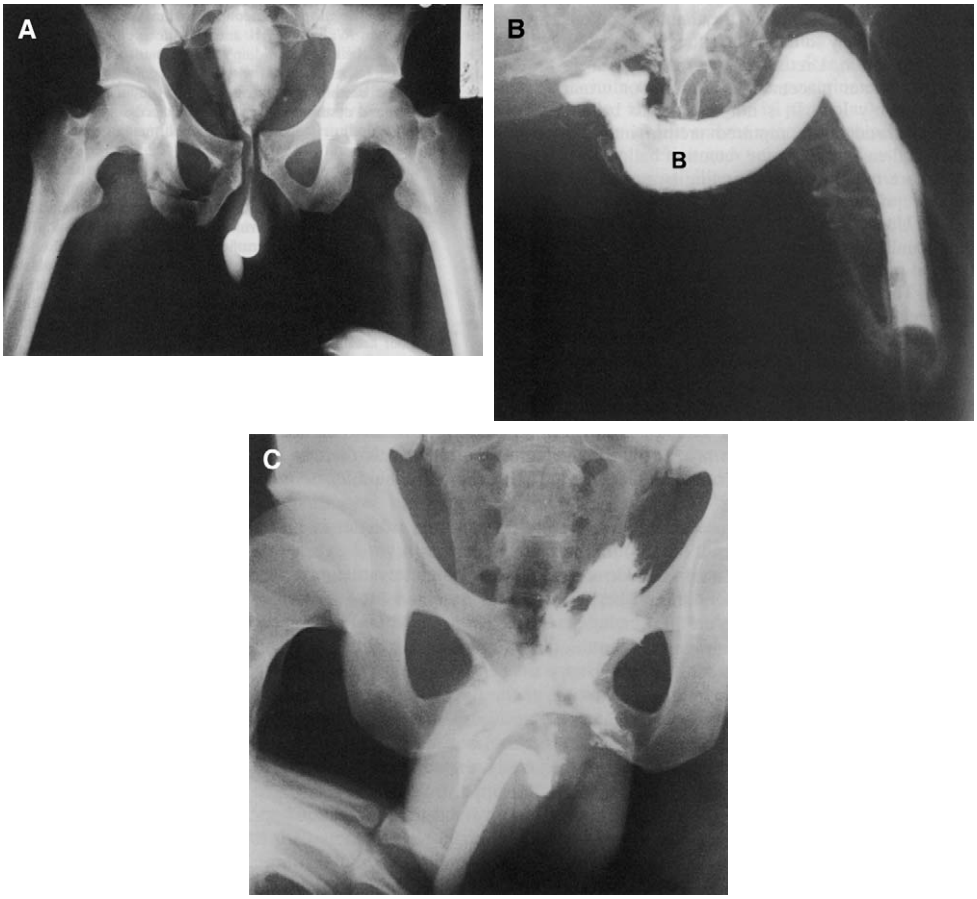

Fig. 5. Prostatomembranous urethral disruption injuries. (*A*) Type 1: Membranous urethra is stretched without rupture. Note the ''pear shaped'' bladder as a result of compression by perivesical hemorrhage. (*B*) Type 2: Complete rupture of the membranous urethra with intact urogenital diaphragm. Extravasation extends into the pelvis only. (*C*) Type 3: Complete rupture of the membranous urethra with disrupted urogenital diaphragm and injury to the proximal bulbous urethra. Extravasation extends into the pelvis as well as into the perineum. (*From* Dixon CM. Diagnosis and acute management of posterior urethral disruptions. In: McAninch JW, editor. Traumatic and reconstructive urology. Philadelphia: W.B. Saunders; 1996. p. 350.)

Failure to void spontaneously may signify compression of the urethra by hematoma but should lead to evaluation of urethral injury by retrograde urethrography. Urethral injury occurs in up to one third of cases and usually consists of partial disruption, although complete transection can result. Retrograde urethrography is mandatory in all patients with blood at the urethral meatus, hematuria of any extent, or inability to void [47].

Penetrating trauma to the urethra is most often caused by firearms, but can also result from stab wounds, industrial accidents, self-mutilation attempts, and bites. In all cases, general principles of management include judicious debridement and hemostasis within the wound, as well as careful exploration and repair of corporal and urethral injuries. Most civilian penile gunshot wounds are caused by low-velocity missiles, which cause damage only in the path of the bullet. Associated wounds of the thigh and pelvis are common, and may require urgent exploration and repair [47].

Urethral injury is determined by careful physical examination, with special attention paid to the trajectory of the bullet and initial hemostasis. The finding of a palpable corporeal defect in combination with an expanding penile hematoma or significant bleeding from the entry and exit wounds is highly predictive of corporeal injury,

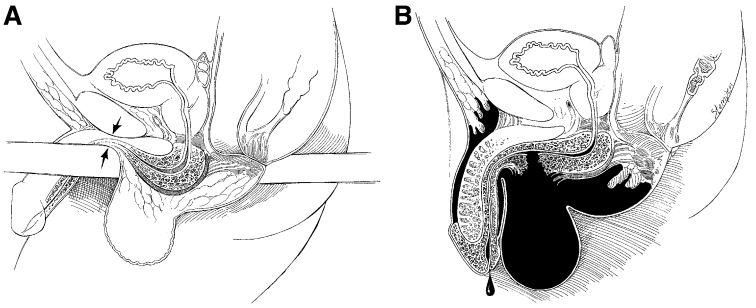

Fig. 6. Mechanism of blunt anterior urethral trauma. (*A*) Straddle injury illustrating the bulbous urethra crushed against the pubic symphysis. (*B*) Resulting urethral disruption with hemorrhage extending along the confines of Colles' fascia. Buck's fascia has been disrupted. (*From* Armenakas NA, McAninch JW. Acute anterior urethral injuries: diagnosis and initial management. In: McAninch JW, editor. Traumatic and reconstructive urology. Philadelphia: W.B. Saunders; 1996. p. 545.)

and should prompt expedient exploration [48]. Urethral injury, which occurs in 25% to 40% of penetrating injuries to the penis, should be excluded with retrograde urethrography in all cases [49]. The bullet may directly lacerate the urethra, or result in urethral injury via delayed necrosis of adjacent spongy tissue. The triad of no blood at the meatus, absence of hematuria, and normal voiding suggests that no urethral injury has occurred.

Penile amputation is an unusual cause of penetrating urethral injury, typically resulting from attempts at self-emasculation in the actively psychotic patient. Penile amputation has also been reported as a rare but devastating complication of circumcision.

Penetrating anterior urethral trauma may be caused by insertion of foreign bodies into the urethra because of mental illness or for autoerotic purposes [50]. In their recent review of a 17-year single-center experience with urethral foreign bodies, Rahman, Elliott, and McAninch reported the most common symptom to be dysuria and frequency. The foreign body was palpable in all patients, and plain images were sufficient to diagnose the location and shape of most of the foreign bodies [51]. Endoscopic retrieval was successful in most cases.

Diagnosis

The presence of an anterior urethral injury is frequently suggested by the history, as outlined above. Any patient with recent blunt or penetrating trauma to the perineum, genitalia, or pelvis should be suspected of harboring a urethral injury [43]. Diagnosis may be delayed in some patients (eg, those with penile fractures, foreign bodies, penile constriction bands) because of embarrassment. Significant delays in diagnosis with massive urinary extravasation may result in sepsis and severe (ie, necrotizing) infection [32]. This presentation may include swelling, discoloration and frank necrosis of the overlying perineal and genital skin.

In the case of penetrating trauma, the type of weapon used and the size and trajectory of the missile or knife are important historical clues. A voiding history, including ability to void, presence of dysuria, and time of last micturition, should be obtained. If available, a voided specimen should be analyzed for the presence of hematuria.

Blood at the meatus is once again the cardinal sign of anterior urethral injury [2]. Dysuria, hematuria, and inability to void are all strongly suggestive of urethral injury. A significant perineal hematoma will be present if the injury has disrupted Buck's fascia and tracks deep to Colles' fascia, creating a characteristic "butterfly" hematoma in the perineum [52]. This occurs in severe straddle injuries. Conversely, the hematoma remains contained in a sleeve distribution along the penile shaft if Buck's fascia remains intact. The urethra may rarely be completely extruded through the genital skin, indicative of complete disruption [53].

Radiographic staging with retrograde urethrography is conducted as described previously. Once again, no attempts at catheterization or voiding should be instituted until the urethral injury has been properly and completely staged.

Classification

The most widely used classification system for anterior urethral injuries was described by

McAninch and Armenakas [44] and is based upon radiographic findings:

1. Contusion: Clinical features suggest urethral injury, but retrograde urethrography is normal.
2. Incomplete disruption: Urethrography demonstrates extravasation, but urethral continuity is partially maintained. Contrast is seen filling the proximal urethra or bladder (Fig. 7).
3. Complete disruption: Urethrography demonstrates extravasation with absent filling of the proximal urethra or bladder. Urethral continuity is disrupted.

Iatrogenic urethral injury

Iatrogenic urethral injuries most commonly result from prolonged or traumatic urethral instrumentation, whereby the delicate mucosa may be partially disrupted. Denudation of the urethral mucosa exposes the underlying vascular spongy tissue to the passage of urine. The inflammatory cascade thus initiated leads to spongiofibrosis, which is scarring within the corpus spongiosum. The clinical manifestation of spongiofibrosis is urethral stricture disease. Most iatrogenic injuries in the anterior urethra occur within the bulbous urethra.

The most frequent cause of acute iatrogenic urethral trauma is related to traumatic Foley catheter removal without prior balloon deflation. These injuries usually result in minor contusions that heal with few sequelae. Chronic indwelling urethral catheters generate prolonged inflammation and pressure necrosis of the urethral mucosa, leading to infection, erosion, and stricture disease. Changes in catheter design, specifically the introduction of less irritative silicone catheters, may have reduced the incidence of this injury.

Fig. 7. Retrograde urethrogram demonstrating incomplete disruption of the anterior urethra secondary to a gunshot wound. Note contrast extravasation inferiorly and superiorly into adjacent corporal tissue. (*From* Miller KS, McAninch JW. Penile fracture and soft tissue injury. In: McAninch JW, editor. Traumatic and reconstructive urology. Philadelphia: W.B. Saunders; 1996. p. 697.)

Intermittent catheterization has a lower incidence of urethral injury when compared with indwelling urethral catheters. Hydrophilic coated catheters have a reduced incidence of urethral trauma and inflammation when compared with non-hydrophilic coated catheters [54] when used for intermittent catheterization.

Various treatments for urethral stricture disease may lead to further urethral injury. Repeated dilations and urethrotomies for stricture disease establish a chronic inflammatory process, which is perpetuated by further urine extravasation and scarring. Barbagli performed histological analysis on posturethrotomy urethral segments that were excised at the time of urethroplasty, and found diffuse inflammation throughout the corpus spongiosum [55]. While the UroLume endoprosthesis has occasionally been used successfully in the treatment of short bulbar strictures, it may also cause further urethral injury and lead to complete obstruction with fibrosis or intrastent hyperplastic response [56].

Urethral injuries have also been attributed to complications of extracorporeal circulation during cardiac revascularization surgery. Perioperative urethral catheterization has been implicated, and a recent retrospective analysis revealed a 6.6% stricture rate compared with 0% for a comparable group with suprapubic urinary drainage [57]. It has been hypothesized that urethral ischemia during extracorporeal circulation causes the injury [58]. In examining this problem, Bamshad recently demonstrated a significant decrease in intraoperative urethral blood flow using laser Doppler flowmetry during cardiopulmonary bypass [59].

Urethral injuries have also been recently reported as a complication of bladder-drained pancreas transplantation and pancreas-kidney transplantation [60]. This complication stems from pancreatic enzymes, which cause mucosal irritation. The injury may range from minor contusion to complete disruption with urinary extravasation [61].

Iatrogenic injuries of the posterior urethra have largely resulted from treatments for benign

prostatic hyperplasia (BPH) as well as those for prostate cancer. These injuries frequently manifest themselves as urethral strictures at variable intervals following the initial treatment. While the term ''posterior urethral stricture'' has been used to encompass both pelvic-fracture prostatomembranous urethral disruptions and strictures within the posterior urethra following iatrogenic trauma, the term is a misnomer. In the case of pelvic-fracture prostatomembranous urethral disruptions, the urethra is not strictured, but rather its continuity is disrupted by intervening scar tissue. In the case of strictures within the posterior urethra following iatrogenic trauma, the urethra remains in continuity with a stenotic lumen. To highlight this distinction, the Société Internationale d'Urologie recently recommended that membranous urethral strictures occurring after transurethral prostate resection (TURP) or radical prostatectomy be referred to as ''sphincter stenoses'' [30].

Anastomotic urethral stricture following radical retropubic prostatectomy occurs in 7% to 17% of patients [62]. The risk increases with prior external beam radiation, as well as any factor that causes anastomotic ischemia (eg, microvascular disease, hypertension) or prolonged anastomotic extravasation [63]. Urethral strictures following TURP occur in 3.1% to 10% of patients [62,64]. Possible causes include postoperative urinary tract infection, urethral abrasion secondary to oversized resectoscopes, and current leakage through the sheath, leading to electrical urethral burn [65].

Urethral injury also occurs during minimally invasive procedures for BPH. A recent review reported on three patients who developed symptomatic mid-prostatic-urethral strictures following transurethral microwave therapy (TUMT) [66]. The investigators postulate that TUMT causes direct thermal or ischemic damage to the urethra despite continuous urethral cooling.

Female urethral injuries

Female urethral injury secondary to trauma is rare, but has been described in association with pelvic fracture in as many as 6% of cases [67]. The injury is usually associated with a vaginal laceration, which is the most frequent clue in reaching the diagnosis. Labial edema, hematuria, and urethrorrhagia may also be present. Unfortunately, these injuries are frequently missed because a vaginal exam is omitted in these severely injured patients.

Imaging of the female urethra in the case of suspected disruption may be difficult. Retrograde urethrography is technically challenging in this setting, and may reveal varying degrees of contrast extravasation and bladder compression by pelvic hematoma. McAninch has suggested that females with suspected urethral injury undergo diagnostic urethroscopy [68].

From a mechanistic standpoint, these injuries present as an anterior longitudinal urethral tear of varying length extending down from the bladder neck into the urethra [69], or as a partial or complete urethral avulsion. Perry and Husmann described 5 patients with longitudinal lacerations in 1992 [69]. In Mundy's recently published series of 12 patients [16], 5 had longitudinal tears, and 7 had complete urethral avulsion injuries. He suggests that avulsion injuries are likely secondary to more severe injury. Because these injuries are rare, a classification system and accepted guidelines for therapy have yet to be formally established.

Summary

Urethral injury originates from a number of well-defined etiologies, as outlined here. Recognition of cardinal signs and symptoms of urethral injury facilitates timely radiographic diagnosis and classification in most cases. This information may then permit appropriate initial management. The astute clinician must maintain a high index of suspicion, as these injuries are both uncommon and frequently overshadowed by multisystem trauma. Although the injury may assume secondary importance in the acute trauma setting, failure to accurately diagnose urethral injuries may lead to sequelae (eg, stricture disease, incontinence, erectile dysfunction), which linger long after other injuries have disappeared.

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