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Thyyar M Ravindranath *

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Review Article

# Trauma to the Ureter and the Urinary Bladder: The Conductor and the Collector

**Thyyar M Ravindranath**

Department of Pediatrics, Morgan Stanley Children's Hospital of New York-Presbyterian, Columbia University Irving Medical Center, Vagelos College of Physicians and Surgeons,630 West 168th Street, New York, New York-10032, USA.

***Corresponding Author:** Thyyar M Ravindranath, Department of Pediatrics, Morgan Stanley Children's Hospital of New York-Presbyterian, Columbia University Irving Medical Center, Vagelos College of Physicians and Surgeons,630 West 168th Street, New York, New York-10032, USA.

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## Abstract

Although uncommon, trauma to the ureter and the urinary bladder is diagnosed based on a suspicion, following multiple abdominal trauma. Both forms of trauma can result from penetrating, blunt, as well as iatrogenic injuries. While bladder trauma more commonly results from blunt injuries, trauma to the ureter more commonly results from penetrating trauma. The diagnosis involves subtle clinical findings which are confirmed by radiological examination. In this brief description of these two types of trauma, the embryology, applied anatomy, physiology, clinical presentation, radiological diagnosis, and treatment options are discussed.

**Keywords:** ureter; urinary bladder; diagnostic modalities; injury classification; treatment; complications

## Introduction

### Epidemiology:

The genitourinary system is involved in 10% of all abdominal injuries [1]. The urinary bladder is the most frequently involved organ while the ureter is injured less often (less than 1%) [2]. However, following multiple abdominal organ injuries, both the urinary bladder and the ureter are involved simultaneously [3]. Blunt trauma, for example motor vehicle accidents, (MVA) accounts for 60%-85% while penetrating trauma, for instance gunshot wounds, (GSW) is responsible for 40% to 15% of the injuries [3]. Injury to the urinary bladder can also be incurred during sporting events. Isolated urinary bladder injury is uncommon and is seen in iatrogenic trauma [1]. Urinary bladder injury can be either extraperitoneal (66%) or intraperitoneal (34%). While extraperitoneal injury is associated with pelvic fracture, especially in children whose pelvis is underdeveloped, intraperitoneal injury results from direct injury to a full bladder. The roof of the urinary bladder is the feeble spot for rupture when it is full due to the weakening of the bladder wall from urachal attachment [4].

The ureter, like urinary bladder, can be involved in blunt, penetrating, and iatrogenic trauma. Penetrating injuries more commonly involve the lower third of the ureter [1] from stab and GSW and are more common (77%) than blunt trauma (23%) [5]. In comparison, iatrogenic injury occurs in less than 1% of cases from pelvic surgery.

### Embryology of the ureter and the bladder:

Urogenital tract develops as an elevation of intermediate mesoderm on each side of the fetus during the 3$^{rd}$ and 5$^{th}$ weeks of the gestational period. Part of the urogenital tract develops into the nephrogenic ridge. Each nephrogenic ridge give raise to a mesonephros and a mesonephric duct. Each mesonephric duct gives rise to an ureteric bud between 4$^{th}$ and 5$^{th}$ week of fetal development and elongates upward and becomes a metanephric duct that develops into the future ureter. During the 7$^{th}$ week of fetal development, the cloacae is divided into the hind gut and the urogenital sinus by the urorectal septum. The upper part of the urogenital sinus develops into the urinary bladder. The incorporation of the metanephric ducts into the bladder at trigone forms the ureterovesical junction [6].

### Applied anatomy:

### The ureter:

Anatomy:

The S shaped ureter is 30 cm. long and is related to the height of an individual. As it courses down, the ureter rests on the psoas muscle, passing medial to the sarco-iliac joint, lateral to the ischial spine, and then moves medially to join the base of the bladder. The ureters are covered by the posterior peritoneum with their lowest portion attached to it while the juxta vesical portion is embedded in the vascular retroperitoneal fat. In women, the ureters are related to the uterine arteries in juxta vesical area.

Histological features:

The ureters are lined by transitional epithelium internally under which is the lamina propria consisting of loose connective tissue. Externally the ureters consist of a smooth muscle layer composed of longitudinal and helical muscles. The adventitia forms the outermost layer and contains fibrous connective tissue.

Blood supply:

Arterial supply:

While the renal arteries supply the upper ureter, the mid-ureter derives its blood supply from internal spermatic or ovarian arteries, and the lower ureters are supplied by common iliac, internal iliac, and vesical arteries.

Venous drainage:

The venous drainage of the ureters follows the arterial supply.

Lymphatic drainage:

The lymphatic drainage of the upper ureters is into the lumbar lymph nodes, that of the mid ureters is into internal iliac and common iliac lymph nodes, and that of the lower ureters is into vesical and hypogastric lymph nodes.

Innervation:

The preganglionic sympathetic innervation is from T10 to L2 segments. The aorticorenal, superior, and inferior hypogastric autonomic plexuses generate the postganglionic fibers. S2 to S4 sacral pelvic splanchnic nerves supply the ureteral parasympathetic innervation [7].

## The bladder:

The bladder, which works as the reservoir for urine, is a muscular organ that holds about 400-500 milliliters of urine. The wall of the bladder is 3-5 millimeters (mm.) thick and is thinner when it is distended. Whereas the adult empty bladder lies behind the pubic symphysis, it is situated higher in children. When the bladder is distended, it perches above the pubic symphysis and can be seen as a bulge in the lower abdomen when overdistended. The obliterated urachus is represented by the median umbilical ligament that extends as a fibrous band from the dome of the bladder to the umbilicus. The ureters enter the posterior aspect of the bladder in an oblique fashion and are 5 centimeters (cm.) apart. The ureteric orifices are located at the ends of a crescentic ridge and are 2.5 cm. apart. The area between the crescentic ridge and the bladder neck forms the trigone. The internal sphincter of the bladder is a thickening that is formed by the intermingling and connecting of muscle fibers of the detrusor which pass distally to become the smooth muscle part of the urethra.

## Anatomical relationship:

In females, the uterus and vagina are located between the bladder and rectum whereas in males, the bladder is placed posteriorly to the seminal vesicles, vas deferens, ureters, and rectum. Superiorly and posteriorly the bladder is covered by peritoneum with close relationship to the small gut and the sigmoid colon. The bladder is closely situated behind the pubic symphysis and when distended it contacts the abdominal wall.

Histological features:

The mucosa of the bladder consists of transitional epithelium followed by a basement layer and lamina propria. The submucosa consists of connective and elastic tissue. Muscle layer is found outside the submucosal layer and is called the detrusor. It consists of smooth muscle fibers that are disposed in longitudinal, circular, and spiral mode in a haphazard organization except near the internal meatus where they form outward longitudinal, middle circular, and inner longitudinal layers.

Blood supply:

Arterial supply:

The arterial supply arises from the anterior trunk of the internal iliac artery via superior, middle, and inferior vesical arteries and branches from the inferior gluteal and obturator arteries. In females, the blood supply also comes from uterine and vaginal arteries.

Venous drainage:

Venous drainage is into the internal iliac vein.

Lymphatic drainage:

The lymphatic drainage is into the external, internal, common iliac, and vesical lymph nodes.

Innervation:

The bladder receives nerve supply from both sympathetic and parasympathetic nerves. The sensory afferent comes from subepithelial nerve endings and between detrusor muscle [7].

## Physiological function of the ureter and the bladder:

As alluded to earlier, the wall of the ureter is composed of smooth muscle arranged in circular, longitudinal, and spiral fashion in an indistinct layer. Peristaltic waves that appear every 1-5 minutes moves urine along the ureters into the bladder in spurts. Although the lower ends of the ureters possess no valves, the oblique entrance of the ureter into the bladder prevents reflux of urine into the urinary bladder during bladder contraction.

## The physiology of micturition:

The urinary bladder exhibits plasticity i.e., the initial volume expansion of the bladder is followed by an increase in intra-vesicular pressure (section 1a) which is followed by a flat portion of the pressure curve (section 1b) and then, as the urinary bladder fills further, there is a sudden rise in pressure (section 11). The initial urge to void is felt at urinary volume of 150 cc. and fullness is felt at 400 cc. The passage of urine is heralded by the relaxation of pelvic muscles which initiates contraction of the detrusor muscle and relaxation of the outer urethral sphincter, which allows urine to pass out via the urethra. The pelvic muscles and external urethral sphincter can be voluntarily contracted once the flow of urine is initiated and thus stop the flow of urine until the urge to void urine presents itself again. Whereas the female urethra empties by gravity,

bulbocavernosus muscle contraction expels urine that remains in the urethra in the male. This voiding reflex has facilitatory and inhibitory centers in the brain stem. The facilitatory center is in the pontine region and the inhibitory center is in the midbrain. The voiding reflex can be initiated by voluntary contraction of the urinary bladder facilitated by abdominal muscle contraction even when the urinary bladder is nearly empty.

The reflex control of the urinary bladder is initiated when the bladder volume reaches 300-400 cc. and involves local stretch receptors in the bladder wall. The afferent pathway is endowed in the pelvic nerves and the efferent pathway consists of parasympathetic fibers that also traverse via the pelvic nerves. The center for reflex control is located in the sacral region of the spinal cord [8].

**Presentation**:

**Injury to the ureter**:

The ureter is injured by penetrating trauma, including iatrogenic injury or blunt trauma with penetrating trauma occurring in two-thirds and blunt trauma encompassing the other third [9, 10]. Penetrating trauma involves the lower one-third of the ureter and is often found among young adult males. Iatrogenic trauma occurs in less than 1% of cases following pelvic and gynecological surgeries. Injury to the ureter must be suspected in multiple traumata involving bowel, bladder, vascular or deceleration injuries [5]. Children are at risk for ureteropelvic injury due to deceleration movement [11].

The location of the ureter amidst surrounding muscles, bony structures, and retroperitoneal setting makes it well protected from injury with an injury incidence of less than 1% [1].

**Clinical features:**

A high index of suspicion is essential in diagnosing ureteral injury although flank pain with ecchymosis, tenderness over the side, hematuria, and hypotension may be present following penetrating trauma to the flank without any specific features pointing to the ureter itself [12].

**Radiological diagnosis:**

Radiological confirmation in a hemodynamically stable patient includes CT urogram which consists of intravenous contrast augmented CT with 10-minute interrupted films helps to precisely diagnose the injury to the ureter. The tell-tale sign of injury to the ureter includes the absence of contrast distal to the injury, contrast extravasation, delayed pyelogram, and hydronephrosis [2].

A retrograde pyelogram is utilized when there is a suspected delayed iatrogenic ureteral injury following revelation of urinary fistula, urinoma, or an abscess. It also allows placement of a stent [1].

Ureteral injury is diagnosed in a hemodynamically unstable patient by exploratory laparotomy either by direct visualization or extravasation of injected dye such as methylene blue [1].

| Injury Grade | Type of Injury | Description of Injury |
|---|---|---|
| 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 |

**Table 1:** Ureter Injury Scale [13]

**Treatment:**

The Management of injury to the ureter is dictated by its hemodynamic status, the site of injury, the status of the ureter, and associated injuries. The majority of injuries are tackled by surgical approach [13]. The main aim is to maintain the ability of the ureter to drain urine.

Once hemodynamic and metabolic stability is attained, the procedure of choice is to use a Foley catheter or a percutaneous nephrostomy tube placement to drain urine followed by delayed definitive surgery [1].

Hemodynamically stable patients can be managed by radiographic studies followed by appropriate surgical approach such as urinary drainage including the usage of a stent. If a non-surgical approach fails then a surgical approach is used [12].

Ureteral reconstruction is more complicated and depends on the site and length of injury. Injury to the ureter above the pelvic brim is repaired with primary anastomosis. Injury to the distal ureter caudad to iliac vessels is tackled by reimplantation into the bladder.

Iatrogenic injury can be managed by stenting.

**Complications:**

Complications include urine leak, urinoma development, periureteral abscess, ureter fistula, and stricture.

**Prognosis:**

The prognosis of ureteral injury depends on the injuries to other organs and the average mortality is 7% [5].

**Injury to the bladder:**

Trauma to the urinary bladder must be suspected in individuals with painful or difficulty in passing urine, lower abdominal pain with bruising, gross hematuria, acute abdomen, entry wound near the suprapubic area with tenderness, ileus, and pelvic fracture especially following blunt trauma [2,10]. Extraperitoneal bladder rupture is associated with pelvic fracture which results in a shearing movement from deformation of the bony pelvis.

**Diagnostic studies:**

Hemodynamically stable patients [12]:

Traumatic urinary bladder injury is best studied by using transurethral cystography with a Foley catheter in place. Three views namely, a plain film, a film with full bladder filled to a volume of 250 cc, and a post-void film are strongly suggested.

**CT cystogram:**

CT cystogram can also be used to diagnose injury to the urinary bladder. Indications include any trauma to the pelvis, pelvic fracture with gross hematuria, blunt trauma with gross hematuria, penetrating trauma with any grade of hematuria, low density free abdominal fluid, blunt trauma with pelvic ring fracture, and over 30 red blood cells per high power field. CT cystogram can also identify bladder neck injury which needs immediate repair in order to prevent urinary incontinence.

### Retrograde urethrogram:

### Indication:

Retrograde urethrogram is performed when CT scan doesn't show the presence of the urinary bladder injury but when it is strongly suspected, especially in the presence of anterior pelvic fracture.

Extraperitoneal bladder rupture on CT shows extravasation of the dye around the base of the bladder restricted to perivascular space and space of Retzius (retro pubic space) with fluid in front and adjacent to the bladder.

### Management:

The management of traumatic bladder injury is based on the American Association for Surgery of Trauma Organ Injury Scale (AASTOIS) [13].

| Grade | Injury type | Description of injury | Treatment |
|---|---|---|---|
| Bladder injury scale | | | |
| I | hematoma | Contusion, intramural hematoma | Nonoperative |
| | Laceration | Partial thickness | Nonoperative |
| II | Laceration | Extraperitoneal bladder wall laceration <2 cm. | May need immediate intervention |
| III | Laceration | Extraperitoneal ≥ 2 cm or intraperitoneal < 2 cm. bladder wall laceration | May need immediate intervention |
| IV | Laceration | Intraperitoneal bladder wall laceration ≥ 2cm laceration | May need immediate intervention |
| V | Laceration | Intraperitoneal or extraperitoneal bladder wall laceration extending into the bladder neck or ureteral orifice (trigone) | May need immediate intervention |

**Table 2:** AASTOIS classification of the urinary bladder injury

In a hemodynamically unstable patient, a catheter drainage is performed until the patient is stabilized and this is followed by definitive procedure.

Extraperitoneal injury to the urinary bladder:

Nonoperative management involves catheter drainage of the bladder or suprapubic cystostomy if there is an associated urethral trauma.

Persistent urine leaks are managed by embalotherapy utilizing copolymer [14].

Absolute indication for surgery:

Penetrating trauma, persistent hematuria, tenacious urine leak (greater than 4 weeks), urine infection, related pelvic organ injury, the presence of foreign body or projecting bone fragments into the urinary bladder, and urinary bladder neck injury [15].

Intraperitoneal injury to the urinary bladder:

Intraperitoneal injury to the bladder is tackled by surgical intervention [16].

A postoperative urinary bladder drainage is essential for the successful healing of the urinary bladder.

## Outcome:

The mortality following the urinary bladder injury is between 0%-34% with a mean of 8%. Factors that determine the outcome include the condition of the patient at the time of admission, hemodynamic instability, fracture to the pelvis, an injury severity score of less than 25, and an undiagnosed urinary leak that can predispose to sepsis [16].

## Conclusion:

The diagnosis of injury to the ureter and to the urinary bladder is fraught with difficulty. A high degree of suspicion with an appropriate analysis of the mechanism of injury in a multiple abdominal trauma victim followed by appropriate radiological studies helps to make the diagnosis. The key aspect of treatment involves establishing urinary drainage.

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