Section A -Research paper

Urological Injures during Obstetric Surgery

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Abstract:

The urethra, bladder, and ureters are particularly susceptible to injury during obstetric surgery. When preventive measures fail, prompt recognition and management of injury can avoid long-term sequelae such as fistula formation and loss of renal function. Intraoperative identification should be the primary goal when an injury occurs, although this is not always possible. Postoperative injury recognition requires a high level of suspicion and vigilance. In addition to history and physical examination, appropriate radiologic studies can be useful in localizing injury and planning management strategies. Some injuries may require Foley catheter drainage or ureteral stenting alone, whereas others will require operative intervention with ureteral resection and reanastomosis or reimplantation. Prompt restoration of urinary drainage or diversion will avoid further renal compromise.

Keywords: Urological Injures, obstetric Surgery, Bladder.

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Introduction:

Recent years have brought a significant increase in the number of births by cesarean section, and as a result there is expected to be an increasing number of patients with adhesions in the pelvis minor on a more frequent basis **(1)**.

Lower urinary tract injuries, including bladder injuries, are associated with an increased morbidity. This includes fistula formation, infections, and renal failure. Furthermore, there is a

high risk of reoperation (60%) following injuries to the urogenital system, and these injuries affect the length of hospitalization and quality of life **(2)**.

Iatrogenic injury of the bladder or ureter is a known complication of abdominal, pelvic or vaginal surgery. Potential sequelae include hemorrhage, sepsis, renal loss and death. The majority of such injuries occur secondary to caesarean section and hysterectomy, with a rising proportion now due to ureteroscopy. However, there remains great variation in the estimation of the frequency of urological injury during these major obstetric and gynecological procedures, which limits the mandate for quality improvement exercises **(3)**

I. Ureteric Injuries:

Ureteric injuries defined as any recognized or unrecognized iatrogenic trauma to the ureter that prevents it from functioning properly or effectively, are rare but constitute one of the most serious complications of gynecological and obstetric surgeries. The concern for ureteral injuries, mostly by gynecologists, is justified because it accounts for 17% of non-obstetric legal action instituted against gynecologists in the USA. Ureteral injuries occur in about 0.2–1% of all pelvic surgeries and 30% of radical hysterectomies. Obstetric and gynecological surgeries, however, account for about 50% of all these injuries **(4)**.

They are quite rare during cesarean deliveries, but cesarean hysterectomies increase the incidence to 3%, which is a 7-fold increase in injuries compared to non-obstetric hysterectomies. The simple fact that 50% of ureteral injuries occur with obstetric and gynecological procedures means that there should be in-depth knowledge of the subject of ureteral injuries among physicians in this specialty. Even in the hands of excellent surgeons, because of the course, relations, and the ability of the pathologies of some pelvic organs to revolve around or displace the ureter, the ureter, may be inadvertently damaged during pelvic surgeries. This review will add to what is already known on this subject and this may help to reduce the incidence of ureteral injuries contributed by the practice of obstetrics and gynecology **(5)**.

Etiology:

The possible causes of iatrogenic ureteric injuries include gynecologic procedures like abdominal hysterectomy, vaginal hysterectomy, anterior colporrhaphy, laparoscopic hysterectomy; obstetric causes and predisposing factors like cesarean hysterectomy, fetal macrosomia, cephalopelvic disproportion, placenta previa, and morbidly adherent placentas involving the pelvic sidewalls, difficult neonatal extraction, prolonged labor, and abnormal fetal lie **(6)**.

Other risk factors for iatrogenic injury include causes of pelvic adhesion like the previous surgeries, endometriosis, and prior radiation therapy, advanced abdominopelvic cancers, enlarged uterus at hysterectomy, cervical fibroids, and broad ligament fibroids, limited experience of the

surgeon, bleeding, and excessive use of diathermy, and transvaginal retrieval of oocytes (TOVR) **(7)**.

Types and Classification:

The types of ureteric injuries include crushing injury, ligation, transection, angulation, excision, ischemia from stripping, electrocoagulation, resection, and a combination of the above. These injuries are classified into 5 grades as described by Moore et al.

- GradeI– Hematoma (contusion or hematoma without devascularization)
- Grade II – Laceration (< 50% transection)
- Grade III – Laceration (≥ 50% transection)
- Grade IV – Laceration (complete transection with < 2 cm)
- Grade V -– Laceration (avulsion with > 2 cm of devascularization)
- Advance one grade if multiple lesions exist **(8)**.

Prevention:

Preventive strategies for ureteric injuries can be general and specific. The general preventive strategies include preoperative radiological assessments like ultrasound scanning, intravenous pyelography (IVP), computerized tomography (CT) scanning, and magnetic resonance imaging (MRI) in selected patients to estimate the size of the masses to be excised and to delineate the path of the ureters **(9)**.

Also, the passage of the urethral catheter is able to monitor urine output in the intra-operative and postoperative periods and also able to identify hematuria or anuria as possible indicators of ureteric injury **(10)**.

During the intraoperative period, general preventive measures include generous surgical exposure to limit the risk of inadvertent ureteric injury, use of appropriate incision to ensure adequate access, and reduce the need for manipulation of the pelvic organs at the surgery. It is very important to avoid blind clamping and ligation when bleeding occurs and identifying the ureters within the operation field to avoid iatrogenic damage. Adequate mobilization of the bladder away from the surgical field with a retractor will also remove the lower segments of the ureters away from inadvertent injuries **(9)**.

The specific prevention of injuries includes ligation and suturing of cardinal ligaments as close to the uterus as possible and mobilization of the ureters laterally and the bladder caudally during abdominal uterine surgeries. During vaginal approaches, uterine vessels should be ligated

as close to the uterus as possible. Proper exposure of the vesical and uterine areas is very necessary as well as pulling off the cervix towards the lower end, to avoid injury to the ureter. While performing anterior colporrhaphy, dissection on lateral angle should be avoided as should the placement of deep sutures during the plication of the bladder. During laparoscopic surgery, mobilization of the fallopian tubes far from the pelvic sidewalls before electrocoagulation **(11)**.

In obstetric procedures, a high index of suspicion is necessary to prevent ureteral injuries. When peripartum hysterectomy becomes inevitable, sound operative techniques and direct visualization of the ureters as well as prophylactic stenting to reduce morbidity during peripartum hysterectomy for placenta accreta are some of the preventive measures. Gentle atraumatic fetal delivery to prevent lateralization of uterine incision when the head of the fetus is deeply impacted during cesarean section in the second stage of labor, careful repair of lateralization to the broad ligament and vagina, identification of the ureter after repair, and evaluation for patency are cardinal to preventing ureteric injuries. Preference for partial or subtotal to total cesarean hysterectomies by less experienced obstetricians is a wise decision during the learning curve **(12)**.

Common Sites of Ureteric Injuries during Obstetric and Gynecological Surgeries:

Approximately half of the entire length of the ureter crosses into the pelvis in a course fraught with hazard. In the female genital tract, some pathologies can distort, encroach or encase the ureter, making it susceptible to iatrogenic injury during gynecological, obstetrics, and pelvic surgeries. The common sites of ureteric injury include the level of the infundibulopelvic ligament where the ureters run parallel to the ovarian vessels and the ureter forms the posterior boundary of the ovarian fossa **(13)**.

In this position, the ureters may be compromised by pelvic adhesions, endometriosis, ovarian tumors, and malignancies. Surgeons performing adnexectomies and laparoscopies should bear this in mind to maintain good traction, avoid uncoordinated dissection, and excessive electrocoagulation to avoid transection or thermal injury to the ureter. At the ischial spine, the ureter lies lateral to the peritoneum of the uterosacral ligament and at the level of the internal os, about 1.5 cm lateral to the cervix, the uterine artery crosses the ureter from above **(14)**.

Large broad ligament fibroid and cervical fibroid can encroach on the ureter. This is the point that the ureter is susceptible to injury during abdominal, vaginal, and laparoscopic hysterectomies. Over the anterior vaginal fornix, the ureter turns anteriorly and medially to enter the bladder, within the ureteric tunnel of the cardiac ligament (tunnel of Wertheim) and the intravesical part, where it traverses the musculature of the bladder **(14)**.

At this point, morbidly adherent placenta and repair of lateralization of uterine incision can make the ureter vulnerable to injuries (**Figure 1**) **(15)**.

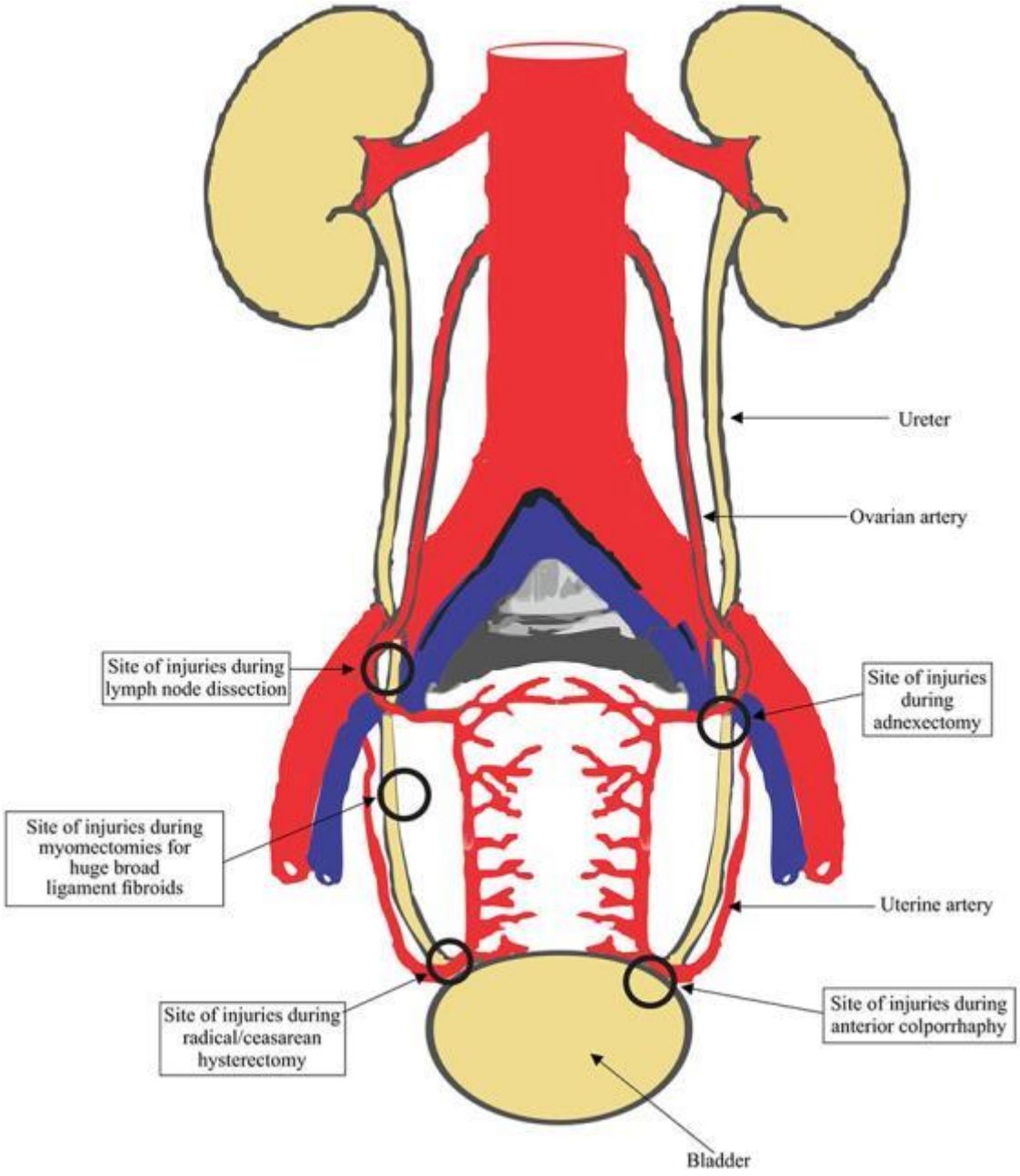

Figure 1: Common sites of ureteral injuries **(15)**

Intraoperative Diagnosis:

Prompt diagnosis and appropriate treatment of identified cases should also be done to prevent the possible complications that may arise from the injuries. Prognosis is better when the diagnosis is made intraoperatively. It is, however, sad to note that approximately 70% of iatrogenic ureteric injuries are diagnosed postoperatively **(9)**.

Intraoperative identification enables prompt repair and decreased morbidity with fewer legal risks. In obstetric surgeries, diagnosis of intraoperative ureteric injuries could be difficult due to the reduced ureteral peristalsis in the third trimester as well as from the hypoperfusion and reduced urinary flow from hypotension and ongoing blood loss. A high degree of suspicion and specific vigilance is needed to decrease the incidence of missed injuries **(16)**.

Intraoperatively, it is important to first ensure adequate exposure of the sites where ureters are susceptible to injuries by packing bowel out of the way, controlling bleeding, and ensuring the theatre lights are appropriately positioned. Ureteral integrity should be checked by isolation and visual inspection of the ureters for contusion, suture ligation, wall discoloration, and lack of capillary refill. Furthermore, where a ureteric injury is suspected intraoperatively, the use of dyes to reveal the site of damage has been advocated. Indigo carmine, methylene blue, sodium fluorescein, phenazopyridine and riboflavin of vitamin B-complex are among the dyes that have been used **(16)**.

Indigo carmine was commonly used before 2014 when the United States Department of Food and Drug Administration announced its worldwide shortage. Sodium fluorescein has been suggested as a good alternative. It results in very bright yellow tinge urine, which can be highly reflective and easier to detect when compared with methylene blue and phenazopyridine. It has also been found to be associated with a more favorable surgeons' satisfaction with fewer side effects **(17)**.

Resistance to cystoscopic passage of a retrograde ureteral catheterization would suggest ureteral obstruction (most definitive diagnostic method). Failure of advancement of the catheter indicates kinking, ligation, or crush injury, while the appearance of the catheter in the abdominal cavity indicates transection, whether partial or complete **(15)**.

On table retrograde pyelography, a common definitive diagnostic method is done via an incision made in the bladder or via a cystoscope. It is a very accurate method of establishing the presence or absence of ureteric injury. It also allows simultaneous placement of the ureteric stent in the injured ureter. It also enables both ureters to be easily examined to rule out bilateral injuries **(7)**.

Clinical Presentation:

The clinical presentation of missed ureteral injury is usually apparent in the first few days following surgery, but it may be delayed by weeks, months, or years depending on the nature of the intraoperative injury. It includes ileus (due to urine within the peritoneal cavity), prolonged post-operative fever or overt urinary sepsis, persistent drainage of fluid from drains, the abdominal wound, or the vagina. Flank pain and costovertebral angle tenderness are common if the ureter has been ligated. An abdominal mass may be felt, representing a urinoma. A continuous leak of urine suggests a ureterovaginal fistula. Hematuria, gross or microscopic, oliguria, elevated serum creatinine levels, persistent abdominal distention, peritonitis, and secondary hypertension have been reported **(18)**.

Postoperative Diagnosis:

Radio diagnostic investigations that could aid the diagnosis of ureteric injuries include intravenous pyelography (IVP), abdominal and pelvic computerized tomography scanning with intravenous contrast, magnetic resonance imaging, retrograde and antegrade pyelography, renal ultrasound scanning, cystoscopy, and dye tests **(19)**.

Management:

Management is based on the timing of diagnosis, the etiology, the length and location of the injury, the patient's overall status, and other associated injuries. It ranges from an excellent reconstruction to a more conservative approach (in unstable patients). The precise nature of the injury should be defined to decide the best method of repair. The general principles of repair include minimal tension on anastomotic sites, preservation of blood supply, adequate debridement, adequate drainage, water-tight spatulated anastomosis, and use of only healthy ureters for re-anastomosis **(20)**.

Preservation of the adventitial sheath and its blood supply with tension-free anastomosis by ureteric mobilization and minimal use of fine absorbable sutures to attain watertight closure should be ensured. Use of peritoneum or omentum to surround the anastomosis (omental wrap) may also be done. An abdominal drain that could be removed in 3–5 days should be placed, and the bladder catheterized for continuous drainage for about a week. The stent may be removed in 3–6 weeks under cystoscopy as an office procedure and an intravenous pyelography (IVP) should be done to confirm ureteral integrity afterward **(20)**.

The options depend on whether the injury is recognized immediately, the level and type of the injury, and the presence of morbidities **(15)**.

Intraoperative Diagnosis and Management:

Most gynecological and obstetric-induced ureteral injuries are located in the distal half of the ureters. If a ureter is included in the ligature and recognized intraoperatively, the ligature should be removed immediately, the integrity of the affected and non-affected ureters should be checked to rule out other associated injuries. The ureteral stent should be inserted and left in-situ of the affected ureter for 3–6 weeks. Intravenous pyelography should be done after the removal of the stent to confirm ureteral patency and exclude stricture **(21)**.

In a case of an inadvertent laceration and the transection less than 50% of the diameter of the ureter, an end-to-end anastomosis of the healthy portions of the damaged ureter is preferable to avoid post-operative persistent ureteral leak or stenosis. This is followed by a ureteral stenting for 3–6 weeks and followed by an IVP as stated above **(7)**.

If the transaction involves greater than 50% or almost the entire width of the ureter, and the defect between the ends of the ureter is of a length where a tension-free anastomosis is possible, the surgical option involves direct ureter to ureter anastomosis (primary uretero-ureterostomy) **(7)**.

This approach is also useful in ureteral contusion as a result of clamping by forceps. In this regard, the clamped segment is resected, and a primary uretero-ureterostomy is done ensuring a tension-free anastomosis. Caution must be exercised, however, as minor-appearing ureteral contusions may stricture later or break down secondary to unappreciated microvascular damage to the ureter. When in doubt, the injured portion of the ureter should be debrided before uretero-ureterostomy. A ureteral stent should be left in-situ for 3–6 weeks and followed with an intravenous pyelography **(15)**.

Another option for the management of ureteral injuries is re-implantation of the ureter into the bladder (ureteroneocystostomy). Ureteroneocystostomy is used to repair injured distal ureter that occurs so close to the bladder that the bladder does not need to be brought up to the ureteral stump with a psoas hitch or Boari procedure **(7)**.

Ureteroneocystostomy involves the creation of a submucosal tunnel for a non-refluxing ureteral repair or a refluxing non-tunneled anastomosis that can be considered if the ureteral length is insufficient for tunneling. The distal portion is ligated using permanent or delayed absorbable suture, making it into a blind-ended tube. The repair should be stented postoperatively **(15)**.

However, Vesico-Psoas hitch (mobilization of the bladder upwards to meet the proximal ureter and then affixing it to the psoas muscle) may be preferable to have a tension-free ureteroneocystostomy and because the distal third of the ureter has a tenuous independent blood supply. The procedure has a high (near 95%) success rate **(20)**.

Injuries to the lower two-thirds of the ureter with long ureteral defects (too long to be bridged by bringing the bladder up in the psoas hitch procedure) can be managed with a Boari

flap. A pedicle of the bladder is swung cephalad and tubularized to bridge the gap to the injured ureter. Abdominal drain for continuous abdominal drainage is done for 3–5 days, the stent is removed after 6 weeks and an IVP is done in 3–6 months after to ensure patency and to rule out stricture **(20)**.

Options for Delayed Recognition:

In cases of intraoperative missed diagnosis and delayed recognition, some urologists suggest stent placement as the first line of therapy for ureteral injuries with delayed recognition, while others recommend that these injuries be repaired openly as soon as possible. These authors cite low complication rates, which can be as low as in the repair of injuries that are recognized immediately **(22)**.

However, delayed diagnosis of the ureteral injury itself increases the complication rate of the repair significantly from 10% to 40% in one series, and some have advocated late repair up to 6 weeks to allow maximal resolution of perioperative inflammation. Usually, failure to place a stent is due to complete obstruction of the ureter or to a gap too long to bridge. If stent placement is achieved, open repair is required only in those patients with persistent leakage or ureteral stricture. The options of open repair depend on the length of the ureteral stricture and associated complications like fistulas, abscess formation, and the presence of urinomas **(22) (Figure)**.

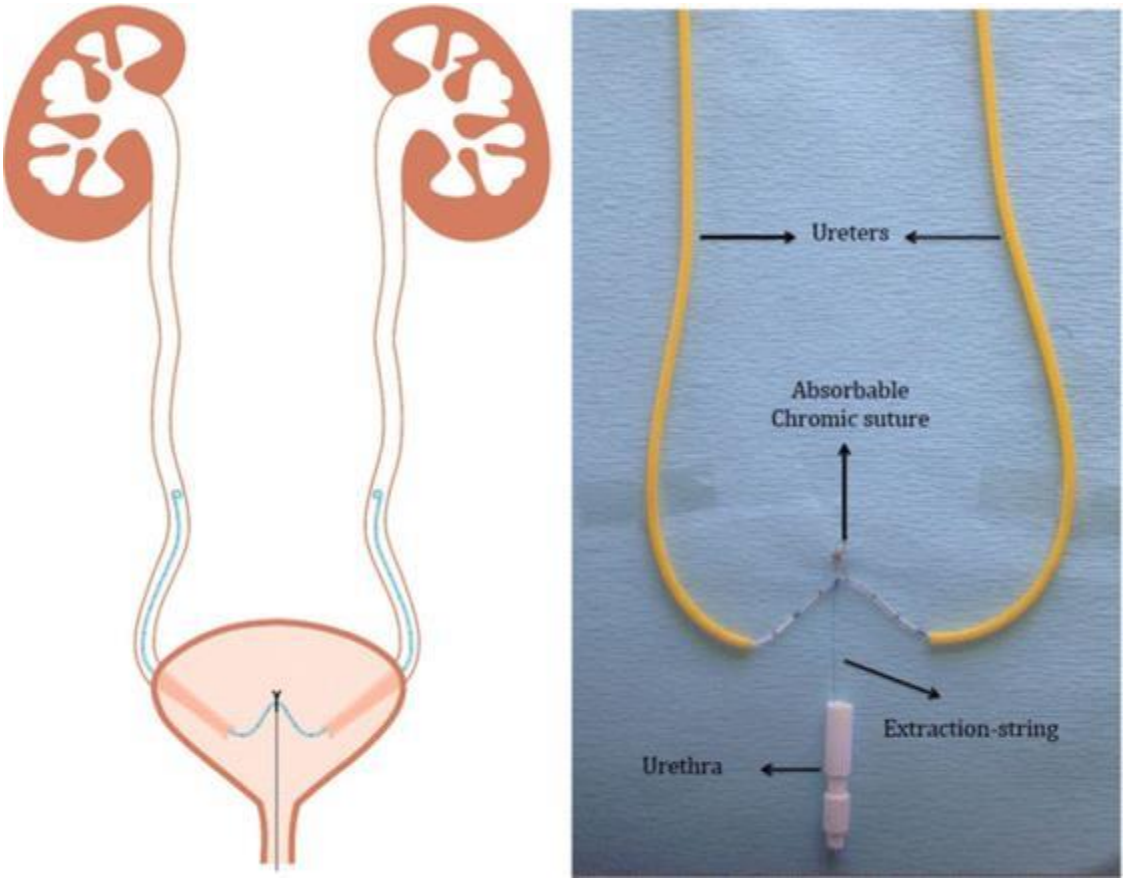

Figure 2: Double J ureteral stent **(15)**

Delayed Ureteral Complications:

When a ureteral injury is diagnosed and repaired at the initial presentation/exploration, rarely is there a high degree of sickness. However, when diagnosis is delayed, sickness including body-wide response to serious infection, loss of kidney function and possible death can occur in up to 50 percent of patients. Rates for surgical removal of the kidney resulting from delayed diagnosis, overall, are seven times as common as when the ureter injury is diagnosed promptly (during surgery). Urine leakage also can cause abscess and scarring of the ureter, leading to obstruction and formation of abnormal passages **(23)**.

Urinary Discharge:

Initially, a ureter that is cut produces no symptoms until a cyst collecting urine causes abdominal swelling, bowel obstruction, infection, fever or low back, side or abdominal pain and/or signs in the membrane that lines the abdominal cavity. Persistent blood in the urine, increase in white blood cells and/or urinary (fluid) leakage from the vagina are other reliable signs of injury. Absorption of the urine by the abdominal membrane will often cause a rise in the serum urea

nitrogen. Such injuries have been managed successfully by a variety of methods, from ureteral stent placement for minor injuries to open surgical repairs **(24)**.

When the patient is medically unstable, has a body-wide response to infection or the injury is not detected for more than two to three weeks, the patient typically requires proximal urinary diversion (that is, a tube leading from the kidney to the outside of the body and, if technically possible, ureteral stent placement), as well as drain placement into the urine-containing cyst. The discharged urine also may cause fibrosis (development of fibrous tissue) behind the abdominal membrane severe enough to cause ureteral obstruction, particularly if the area is not drained properly. At two to three weeks after surgery, re-exploration is typically difficult and fraught with danger because of inflammation, fibrosis, adhesions, blood clotting and distorted anatomy. Definitive repair is performed in a delayed/staged fashion **(24)**.

Fistulas:

Fistulas (abnormal passages – mainly ureterovaginal) are rare after ureteral repair. They usually develop when the ureteral injury is undiagnosed during the operation, and the ureter undergoes delayed tissue death and/or narrowing (obstruction). Other factors that contribute to fistula formation are infection (abscess, peritonitis), inflammation, foreign body and tumor formation. A history of prior pelvic irradiation (that is, for cervical cancer) is another independent risk factor, increasing the risk for fistula formation after hysterectomy by three to fourfold and complicating the difficulty of fistula repair. Ureteral fistulas usually do not require an open operation and typically close spontaneously with proper drainage and ureteral stenting **(25)**.

Stricture:

Stricture (narrowing) develops when a ureter with deficient blood supply, often from a certain type dissection, heals by scar tissue. Side or abdominal pain and urinary tract infection/pyelonephritis (kidney inflammation) are commonly seen. Ureteral strictures that are diagnosed early (within six to12 weeks), are in the portion away from the kidney and are relatively short in length (less than 2 cm) can be managed successfully (in about 50 to 80 percent of cases) by balloon dilatation or endoscopic incision and stenting for six weeks. For endoscopic failures, an open surgical repair is necessary. When the stricture is discovered late, particularly dense or long, or radiation induced, open segmental removal and repair are usually necessary **(26)**.

Bladder injuries:

Injuries to the bladder occur in up to 10% of abdominal trauma and may be associated with significant morbidity and mortality (10-22%). Bladder injuries more specifically may result from blunt or penetrating trauma and iatrogenic injury during surgery. Cystography may be performed to diagnose the presence and grade of bladder injury which will subsequently guide whether conservatively management or surgical intervention is required **(27)**.

Etiology:

Isolated bladder injuries are rare, with most being secondary to iatrogenic causes. Iatrogenic bladder injuries are highest in gynecologic and urologic surgeries, given the proximity of structures in the pelvis, but may also occur with general and orthopedic surgeries. Procedures associated with the highest incidence of bladder injuries include vaginal hysterectomies (0.4-6.3%), urethral or retropubic slings (6-50%), and transurethral resection of the bladder (3.5-58%) **(28)**.

The American Association of Surgery for Trauma (AAST) developed the Organ Injury Scale to provide a common language to facilitate clinical decision making and research. It is based on the degree of anatomical disruption with Grade I being mild to Grade V being lethal. Bladder injury is graded as a contusion or partial laceration (Grade I) to complete laceration (Grades II-V) **(Table) (8)**.

Grade I injuries, contusions of the bladder wall and partial thickness lacerations, can lead to self-limiting intramural hematoma formation. These minor injuries are the most common injuries and represent a third of all cases of bladder injury. EP injuries are Grade II (<2 cm) or Grade III (≥2 cm). IP injuries are Grade III (<2 cm) or Grade IV (≥2 cm). Bladder injuries may extend down to the bladder neck and involve the ureteral orifices or trigone (Grade V). Detecting these injuries is essential because an unrecognized injury to the bladder neck may cause urinary incontinence or require a more complex repair i.e., ureteral reimplantation, in the setting of an injury to the ureteral orifice **(29)**.

Table 1: American Association for the Surgery of Trauma Bladder Organ Injury Scale **(8)**

Bladder Injury Description		
Grade	**Injury**	Description
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**	Laceration extending into bladder neck or ureteral orifice (trigone)

Clinical Presentation:

Prompt recognition of bladder trauma can prevent severe complications due to urinary leakage, which include sepsis, peritonitis, abscess, urinoma, fistulas, and electrolyte disturbances through reabsorption. Morbidity and mortality from bladder injuries have been shown to correlate

with injury severity scores >15, systolic blood pressure <90 mmHg, and concomitant pelvic fractures. Bladder injuries are also associated with longer hospital stays and carry a significant risk of morbidity and potential for increased cost of care **(30)**.

Gross hematuria, seen in 67-95% of cases, is the most classical symptom associated with bladder trauma. Microscopic hematuria may be seen in 5% of cases. Other signs such as the mechanism of injury, associated pelvic fracture, suprapubic tenderness, low urine output, difficulty voiding, elevated creatinine, abdominal hematoma, edema of the perineum and upper thighs, and shock should all raise the index of suspicion for a bladder injury. In the case of penetrating injuries, especially GSWs, entrance and exit wounds in the lower abdomen, perineum and buttocks may be visualized and should be traced **(31)**.

Iatrogenic bladder injuries during surgery may present with clear fluid or appearance of the urethral catheter in the surgical field, blood or gas in the urine drainage bag, fatty tissue or bowel seen on cystography, low return of bladder irrigation fluid, and inability to distend the bladder or conversely abdominal distension. This should prompt urological consultation **(32)**.

While isolated bladder injuries are infrequent, risk factors include young age, male gender, alcohol intoxication, and trauma. Alcohol causes distension of the bladder and increases the risk of blunt trauma from motor-vehicle accidents. Isolated bladder injuries may have a delay in presentation and diagnosis, sometimes of up to five days, resulting in increased blood urea nitrogen and creatinine through reabsorption in the peritoneum. Therefore, a high index of suspicion in the emergency room should be maintained for patients presenting with risk factors mentioned previously **(33)**.

Clinical Assessment:

Trauma patients should undergo assessment per Advanced Trauma Life Support protocol developed by the American College of Surgeons. Hemodynamically unstable patients should not undergo acute evaluation of bladder trauma, but rather be taken for immediate surgical exploration. Gross hematuria in the setting of a pelvic fracture is an absolute indication for cystography, as bladder injury is present in 29% of such cases. Gross hematuria refers to visible blood from the urinary tract while microscopic hematuria can only be detected on urinalysis. Gross hematuria without pelvic fracture and microscopic hematuria with pelvic fractures are relative indications for cystography if there is clinical suspicion **(34)**.

Clinical suspicion may include mechanism of injury, pubic symphysis diastasis, >1 cm obturator ring fracture displacement, penetrating injuries with pelvic trajectories, inability to void, low urine output, increased blood urea nitrogen or creatinine, abdominal distension, suprapubic pain, or urinary ascites seen on imaging. A small number of patients with pelvic fractures (0.6-5%) will present with microscopic hematuria; however, microscopic hematuria, in general, is a poor predictor of bladder injury **(34)**.

While X-ray cystography has been traditionally used to evaluate for bladder injury, most centers are moving towards the utility of Computed Tomography (CT) cystography due to increased convenience and rapid turnover time. CT cystography is particularly beneficial when other abdominal organs require imaging, as it can detect multiple injuries including the source of hematuria. The European Association of Urology (EAU) recommends CT cystography be used in the context of other possible abdominal trauma, while the American Urological Association (AUA) guidelines do not specifically address the use of CT versus X-ray **(30)**.

For both CT and X-ray cystography, contrast is instilled in the bladder in a retrograde manner via gravity filling through a catheter. The bladder is commonly distended with at least 300 mL of contrast material. X-ray cystography requires a minimum plain film, complete filling film, and post-drainage film. The post-drainage film is utilized to identify a posterior bladder injury that may be masked by a bladder filled with contrast. Oblique X-ray images may also be used to help delineate the location of a bladder injury. In comparison, the post-drainage film is not required in CT cystography since three-dimensional reconstruction allows for circumferential evaluation of the bladder and localization of the laceration **(35)**.

CT cystography is equally effective as retrograde cystography in the diagnosis of bladder rupture with similar specificity and sensitivities. Compared to X-ray cystography, CT is more expensive and confers greater radiation. However, CT takes less time and includes more detail of the surrounding pelvic structures. While both are equally effective in detecting bladder rupture, we expect the trend to continue towards CT cystography **(36)**.

Contrast material outside the bladder is an indication of bladder injury **(Figure)**. In IP ruptures, contrast material may extravasate into the paracolic gutters and outline loops of bowel. In EP ruptures, contrast material is seen in the retropubic space, anterior peritoneal spaces, and between the superficial soft tissue layers of the thighs. Conversely, in the case of bladder contusion or interstitial bladder injury, there is no contrast extravasation outside the bladder. Contusions appear normal on cystography while interstitial injuries may present as an intramural hematoma **(37)**.

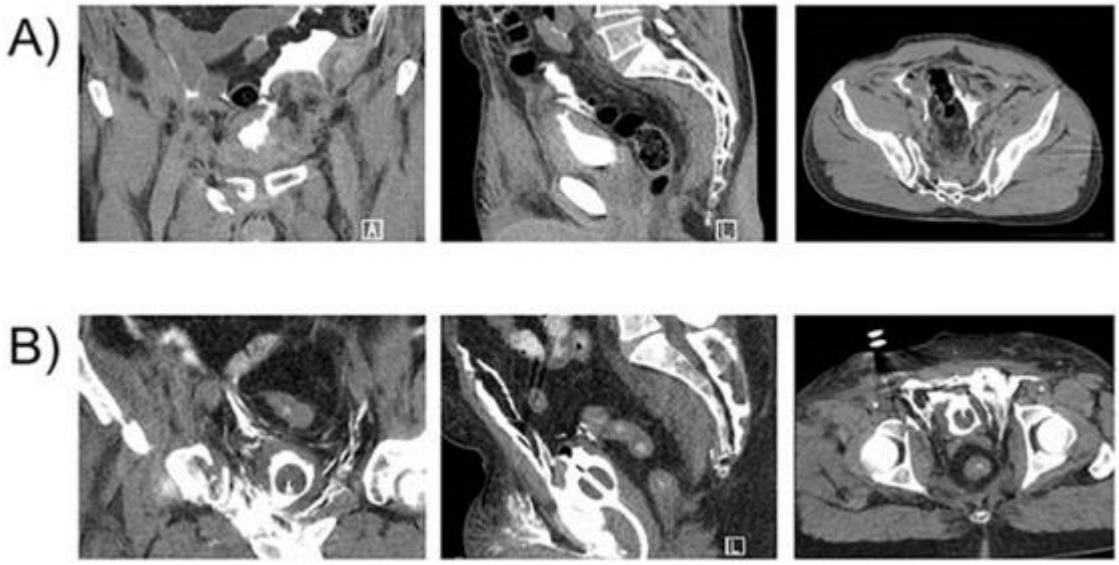

Figure 3: Coronal, sagittal, and axial images for an A) intraperitoneal and B) extra peritoneal bladder injury **(38)**

In the case of an intra-operative bladder injury, the EAU guidelines recommend the use of cystoscopy for evaluation of suspected bladder injuries. Alternatively, for patients undergoing intraabdominal surgery, an indwelling urethral catheter may be filled while the abdomen is inspected for fluid extravasation from the bladder. While routine cystoscopy after gynecological or urological procedures is controversial, it is warranted if bladder injury is suspected after hysterectomies, sling operations (especially via retropubic route), or transvaginal mesh procedures. This is important as bladder injuries may be missed. In one study 67% of bladder injuries during hysterectomy were not detected until after cystoscopy **(39)**.

Abdominal Hysterectomy:

In gynecologic surgery, bladder injury most commonly occurs during abdominal hysterectomy. The bladder can be injured at four specific sites. If a bladder injury is noted at this time, it usually can be easily managed by a two- or three-layer closure with absorbable suture and Foley catheter bladder drainage. Retrograde bladder filling with blue-colored saline again makes bladder injury diagnosis easier **(40)**.

Vaginal Hysterectomy:

Most bladder injuries during vaginal hysterectomy are in a specific area of the bladder base. For such bladder injuries, cystoscopy is often helpful to identify the location of the injury. If there is any suspicion of an accompanying ureteral injury, indigo carmine should be injected through the veins and the ureteral openings observed for blue dye. Once ureteral injury is ruled out, the bladder injury can be repaired in two or three layers. The adequacy (watertightness) of the bladder closure can be tested by retrograde filling of the bladder with saline. A Foley catheter is typically left in

place for seven to 14 days. After the bladder laceration has been repaired, the vaginal hysterectomy can be completed and/or anterior surgical repair of the vaginal wall performed **(41)**.

Laparoscopy:

When injured, the bladder is usually penetrated by, and on initial placement of, the Veress needle or trocar (a surgical instrument). Trocar injuries are typically to the bladder dome and have an entry and exit wound. To avoid bladder injuries, it is essential that the bladder is decompressed by a Foley catheter at the beginning of the case. The position of the bladder should be assessed on initial examination with the laparoscope. All secondary trocars should be placed under direct visualization. Bladder injuries occur most often with midline and lower abdominal trocar placement. A full bladder or one with distorted anatomy from previous pelvic surgery, endometriosis or adhesions is more likely to be injured laparoscopically **(42)**.

During the operation, the diagnosis of bladder injury is suggested by the presence of gas filling up the Foley bag or visibly bloody urine in the Foley bag. Other signs of injury are urinary/fluid drainage from a secondary trocar site incision, or fluid pooling in the abdomen/pelvis. If a bladder injury is suspected, the bladder should be filled with methylene blue-colored saline. The forcing out of fluid/dye indicates a bladder injury inside the abdominal membrane. If there is no fluid forced out and a bladder injury outside the abdominal membrane is suspected, a cystogram (X-ray of the bladder after injection of contrast medium) should be performed. Injuries outside the abdominal membrane are managed conservatively through prolonged Foley drainage. Delayed diagnosis of bladder injury also is done by cystography. Irritation of the abdominal membrane that persists more 12 hours after laparoscopy also should raise suspicion of an undiagnosed bladder injury **(42)**.

Veress needle injuries and other small injuries to the bladder can be successfully managed conservatively by catheter drainage for seven to 14 days followed by cystography. Large bladder injuries, such as from 5- or 10-mm trocar or surgical dissection, often require suturing the injuries closed (either laparoscopically or by open repair) and prolonged catheter drainage. A bladder injury recognized by laser or electrocautery should be closely evaluated and typically managed with catheter drainage for five to 10 days. Sharp dissection, electrocautery and laser bladder injuries also have been reported during laparoscopic-assisted vaginal hysterectomy, adnexectomy (removal of one of the uterine tubes and an ovary), diagnostic laparoscopy and endometriosis surgery **(43)**.

Delayed Bladder Injury/Diagnosis:

Cystography with a post-drainage X-ray will enable the surgeon to assess injury inside and/or outside the abdominal membrane. Injuries inside the abdominal membrane require surgical closure and drainage, whereas injuries outside the abdominal membrane can be successfully managed through prolonged Foley catheter drainage. Decreased urine output, absent or defective

urine excretion, an excess of urine, elevated blood urea nitrogen, the presence of blood in the urine, bruising and abdominal swelling suggest a bladder injury has been missed **(44)**.

Undiagnosed injuries to the bladder that occur during surgery typically become evident days to weeks after surgery. In patients with previous pelvic irradiation, fistulas can occur months to even years after hysterectomy. Typical delayed bladder complications are various forms of fistulas **(44)**.

Management:

A bladder contusion is a diagnosis of exclusion in patients presenting with hematuria in the setting of blunt trauma for which no observable cause is found. Contusions do not necessitate treatment unless significant hemorrhage is present for which a large bore catheter can be used for drainage and irrigation if required. Interstitial bladder injuries can be managed with prolonged bladder rest with a urethral catheter, and a repeat cystogram is not necessary **(29)**.

Surgical management of a bladder injury is warranted for IP injuries since they carry the risk of sepsis, tend to be larger injuries, and have a higher associated risk of morbidity and mortality when compared to EP injuries **(29)**.

IP injuries therefore require surgical exploration, which is usually performed through a lower midline or Pfannenstiel incision. The laceration should be sutured in one or two layers with an absorbable running suture. After the bladder injury has been repaired, the closure may be tested by filling the bladder in a retrograde fashion through a urethral catheter. Furthermore, use of a colored agent, such as methylene blue, may help to identify leaks during bladder filling **(34)**.

An abdominal drain may also be placed to evaluate for post-operative urine leaks. There are no current guidelines on the optimal length of time for catheter placement after bladder repair, but 7-14 days has been reported and is commonly used AUA guidelines recommend against using suprapubic catheters following bladder repairs, as urethral catheters are sufficient in the majority of cases. In fact, drainage with urethral catheters have been associated with shorter hospital stays and lower morbidity compared to combined drainage with suprapubic and urethral catheters **(34)**.

EP injuries are usually managed conservatively, with bladder drainage via catheter followed by a cystogram to confirm healing of the injury. In a study by Johnsen et al., cystogram revealed continued extravasation in at least 18% of patients with EP injuries managed with catheters, suggesting confirmatory cystography may still be of some utility **(45)**.

The majority of ruptures heal by three weeks; if the injury has not healed by four weeks, AUA guidelines recommend surgical repairs. The guidelines also recommend surgery for EP bladder injuries when there is persistent hematuria, associated pelvic organ injury, the presence of foreign bodies or projecting bones in the bladder, ongoing urinary leak, and penetrating trauma. Other indications may include concomitant vaginal or rectal lacerations, inadequate

drainage via urethral catheters, bladder neck injuries, and internal fixation of pelvic fractures. Concurrent cystorrhaphy during surgical intervention for other abdominal injuries has also been shown to reduce urologic complications, time in intensive care, and overall hospital stay. Similarly, EAU guidelines recommend concomitant cystorrhaphy during laparotomy to decrease infective complications **(46)**.

Complications:

Complications can occur either due to bladder trauma itself or due to surgery for bladder repair. Following complications can occur:

- Urinary incontinence.
- Wound dehiscence: drainage from wound site should not be confused with urine leak.
- Decreased bladder capacity from over-debridement.
- Persistent urinary extravasation.
- Hemorrhage can occur with violation of pelvic hemorrhage.
- A pelvic abscess can develop from an infected hematoma.
- Intraabdominal infection.
- Fistula.
- Urinary tract infection.
- Urinary urgency **(47)**.

II. Urethral injury:

Iatrogenic urethral injury represents the most common mechanism of urethral trauma in modern surgical practice. Iatrogenic urethral injury may result from inappropriate catheterization, instrumentation, or surgery. Sequelae of urethral injury include stricture and urethrovaginal fistula formation **(48)**.

Incidence and etiology:

While much is written about urethral injury in male patients, assessing rates of iatrogenic urethral injury in women poses a greater epidemiological challenge. Urethral stricture or defects associated with urethrovaginal fistula are rare and the most common cause of urethral damage in well-resourced countries is iatrogenic injury resulting from surgical complication **(49)**.

Urethrovaginal fistula may occur as a result of surgical treatment of stress incontinence in women with bulking agents or mid-urethral tapes. Blaivas et al. describes repair of 8 urethrovaginal fistulae, which developed following mid urethral sling surgery. Fistulae have also been reported in association with urethral diverticula and their subsequent repair. They have even been reported to occur in the conservative treatment of prolapse with pessaries **(49)**.

Diagnosis:

Women with urethral strictures may present with acute urinary retention or more indolent urinary symptoms of hesitancy, poor flow, frequency, urgency and dysuria. Symptoms of an urethrovaginal fistula are largely dependent on its size and location. More distal fistulae may be asymptomatic or present with spraying of urinary stream. Those located at the bladder neck may present with continuous urinary leakage, whereas those located more proximally may be associated with stress urinary incontinence **(50)**.

Diagnosis of urethral stricture or urethrovaginal fistula is generally made on clinical examination and with cystourethroscopy. A dye test as described above may aid in the diagnosis. MRI imaging can also be beneficial. Video urodynamics allows evaluation of urinary incontinence and in the case of fistula, allows assessment of its relationship to the bladder neck and urethra and examination for concomitant VVF **(50)**.

Management:

If a diagnosis of urethral trauma is made, generally a period of urethral catheterization for up to 4e6 weeks will be adequate for healing. A wide variety of female urethroplasty techniques are available and may need to be used in conjunction with repair of urethrovaginal fistulae. The surgical repair of urethrovaginal fistulae is challenging with many patients requiring concurrent or subsequent intervention for stress urinary incontinence. If the fistula is a result of a foreign body, such as a mid-urethral sling, this will generally need to be excised widely with interposition of healthy tissue or flaps if necessary **(50)**.

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