Clinical Expert Series

CME

Prevention, Recognition, and Management of Urologic Injuries During Gynecologic Surgery

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The urethra, bladder, and ureters are particularly susceptible to injury during gynecologic 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.

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Gynecologic surgery carries an inherent risk to the urogenital tract for reasons of proximity, prior surgery, and pathology. The long-term consequences of an undiagnosed injury to the bladder can include fistula formation and altered urinary patterns. The long-term consequences of an undiagnosed injury to the ureter can include fistula formation, stricture, or obstruction, resulting in renal failure. Although less common, there can be injury to the urethra, resulting in voiding dysfunction and pain. Good surgical technique, preventive measures, early diagnosis, and evidence-based management are the keys to reducing morbidity.

Reported risk factors for bladder and ureteral injury include history of a cesarean delivery, prior abdominal surgery, endometriosis, adhesions, broad ligament leiomyomas, and low-volume surgeons, defined as surgeons who perform less than 10 hysterectomies per year.[1] Grade V cystotomy (extending into the bladder neck or trigone) has been associated with the development of vesicovaginal fistula after hysterectomy. Other factors that may contribute to fistula formation are concurrent ureteral injury, tobacco use, more difficult surgery as evidenced by longer operative times, and operative blood loss in excess of 1,000 mL.[2,3]

In this article, we describe the most up-to-date methods for preventing, recognizing, and managing injury to the urogenital tract. We present injury types and mechanisms and discuss injury localization. We present conservative and surgical approaches as well as suggest when additional expertise should be sought.

ANATOMY

Injury to the urethra can occur at the time of midurethral sling placement, anterior vaginal wall defect repair, or in conjunction with an injury to the trigone of the bladder. The urethra is approximately 5 cm in length, arises from the lower portion of the trigone, at the vesicle neck, and runs parallel along the anterior surface of the vagina.

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Bladder injury is the most commonly reported urologic complication of gynecologic surgery as a result of its close proximity to the lower uterus and upper vagina. The bladder is composed of a base and a dome. The base includes the trigone and thickening of the detrusor muscle, which rests anterior to the upper vagina. Each ureter inserts into one of the two upper corners of the trigone. The dome is the remainder of the bladder and the most commonly injured portion.

The ureter is also at risk of injury at the time of gynecologic surgery, primarily because of its close proximity to the cervix, uterine artery, and the ovarian vessels near the pelvic brim. This retroperitoneal structure is approximately 25–30 cm in length from the renal pelvis to the trigone and can be divided into thirds. The proximal third arises from the renal pelvis and descends along the ventral surface of the psoas muscle. In its midportion, the ovarian vessels cross the ureter anteriorly as the ureter approaches the pelvic brim. The ureter then passes over the bifurcation of the internal and external iliac vessels. The distal third of the ureter descends into the pelvis, where it lies in a connective tissue sheath and is loosely attached to the medial leaf of the broad ligament. The ureter is least likely to be injured where it is seen traveling and peristalzing in the medial leaf of the broad ligament. It then passes through the cardinal ligament, traveling along the upper anterior vagina, passing within the bladder wall, and inserting to form a ureteral orifice.

The ureter is at greatest risk of injury where it courses beneath the uterine vessels, approximately 2.3 cm anterolateral to the cervix. Importantly, in a small subset of women, the distance between the cervix and the ureter may be less than 0.5 cm.[4] The ureter can also be injured at the level of the pelvic brim, when the ovarian vessels are ligated, or near the ureterovesical junction during dissection of the bladder from the upper vagina or closure of the vaginal cuff during hysterectomy.

INCIDENCE AND TYPES OF INJURIES

The risk of urologic injury during gynecologic surgery varies greatly according to the procedure being performed and the approach used. Other issues that increase injury risk include scaring and anatomic deviation related to previous surgery or pathology, most notably endometriosis and gynecologic malignancies. The types of injuries sustained by the urethra, bladder, and ureters are detailed in Box 1.

Box 1. Types of Urologic Injuries

Bladder

- Contusion
- Thermal injury
- Laceration
- Perforation
- Erosion of suture or mesh
- Intravesical suture or mesh

Ureteral

- Contusion
- Thermal injury
- Laceration
- Transection
- Ligation
- Kinking
- Devascularization

Urethral

- Laceration
- Perforation
- Erosion of mesh
- Intraurethral mesh

The urethra can sustain laceration at the time of suburethral dissection of the anterior vagina in preparation for a midurethral sling. This is particularly true when there is a history of repeated vaginal surgery, resulting in thinning and fibrosis. Perforation of the urethra can also occur with trocar placement at an estimated incidence of 0.88% for retropubic tapes and 1.09% for transobturator tapes.[5]

The bladder can be injured during abdominal or laparoscopic hysterectomy at the time of dissection from the lower uterus and upper vagina, particularly if adhesive disease is present. It can alternatively be injured when entering the anterior cul de sac during a vaginal hysterectomy. Injury can occur as a result of incorporation of the bladder into a clamp, sharp and blunt dissection, or with the use of energy devices. In the case of thermal injury, there is tissue surrounding the visible lesion that is considered nonviable.

The dome is the most commonly injured portion of the bladder, although aggressive dissection of the bladder off the upper anterior vagina or attempted entry into the anterior cul de sac distal to the cervicovaginal junction could pose a threat to the trigone or bladder neck. In a large Finnish study of more than 5,000 hysterectomies, the rate of bladder injury was 0.9%, 0.6%, and 1% for the abdominal, vaginal, and laparoscopic approaches, respectively.[6] During placement of a tension-free vaginal tape, bladder injury occurs in 3–9% of cases.[7–11] The risk

associated with transobturator tape is much lower with a bladder perforation rate of 0.5%.[12]

The ureter can be contused, devascularized, kinked, ligated, lacerated, and transected. Thermal injury can also occur when energy devices are deployed in close proximity to the ureter, particularly at the level of the uterine artery. Extensive ureterolysis can result in devascularization of the ureter.

As discussed earlier, the most common sites of laceration and transection are at the pelvic brim, the cardinal ligament, and the ureterovesical junction. The rate of ureteral injury in the previously mentioned Finnish study was 0.3%, 0.04%, and 0.3% for the abdominal, vaginal, and laparoscopic approaches, respectively. Kinking and ligation can occur at the time of pelvic organ prolapse surgery, particularly when the uterosacral ligaments are affixed to the upper vagina and brought toward the midline. Ureteral injury is reported to be as high as 11% with uterosacral ligament suspension.[13]

Fistula formation after hysterectomy occurs between the bladder and vagina as well as the ureter and vagina. This can be the result of an undiagnosed injury, devascularization, or thermal damage. In the most recent Cochrane review of surgical approach to hysterectomy for benign conditions, there was no difference in long-term fistula formation when comparing laparoscopic hysterectomy with abdominal hysterectomy and laparoscopic hysterectomy with vaginal hysterectomy.[14] A recent meta-analysis demonstrated that injury to the urinary tract at the time of laparoscopic hysterectomy resulted in a vesicovaginal fistula and ureterovaginal fistula rate of 3.4% and 2.4%, respectively.[15]

PREVENTION

The primary means of preventing injury is a clear understanding of anatomy, particularly if there is suspicion of an anomaly. All gynecologic surgeons should understand the location of the ureter. An understanding of the most common mechanism and location of injury to each structure is also invaluable. Finally, one should consider the effects of prior operative procedures and apply sound surgical technique.

The urethra can be injured at the time of midurethral sling insertion, both from the vaginal dissection and trocar placement. When there is a history of prior anterior vaginal surgery, there is a possibility of encountering fibrosis when dissecting the vaginal epithelium from the pubocervical fascia. In this case, injury to the urethra may be unavoidable, and detection becomes all the more important. To avoid perforation at the time of retropubic sling placement, the urethra and bladder neck are deflected with a rigid catheter guide. The handle of the guide is directed toward the side of trocar placement, which deflects the urethra and tip of the catheter guide away from the trocar. When performing vaginal surgery with tissue dissection near the urethra, a Foley catheter or a rigid urethral catheter may be placed to enable palpation of the length of the urethra.

Cystotomy is a complication observed in all modalities of hysterectomy, particularly when there is a history of prior cesarean delivery and adhesions are encountered intraoperatively. When the borders of the bladder are unclear, fluid or CO_2 gas can be instilled to better define where the dissection should be initiated.

During vaginal hysterectomy, cystotomy is often a result of being in the incorrect tissue plane or the result of scarring from prior surgery. It is important to both see and feel tissue planes. Once the correct tissue plane is missed, it is more difficult to get back to the correct tissue plane. Our approach is to make the initial anterior vaginal incision at the level of the first vaginal rugae. The first vaginal rugae is visualized, and the underlying tissue is felt to be mobile. Entering the vaginal epithelium at this level will better allow the surgeon to avoid digging too deeply into the cervical stroma and thus miss the correct surgical plane. Sharp dissection and a scissor-spreading technique are used to develop the fascial plane at the level of the pubocervical fascia. If a Foley catheter has been inserted into the bladder, this can be palpated to better understand its relationship of the bladder to the pubocervical fascia. A right-angle retractor can be used to retract the bladder away from the dissection plane. Once the pubocervical fascia has been entered with scissor tips pointing toward the cervix, the peritoneum is entered next. The peritoneum can often be seen as a thin white transverse line, because it is usually folded on itself. Because this fold is in a transverse plane, making the incision while holding the scissor in a vertical plane makes entering the plane easier and will usually help avoid making multiple attempts to get into the peritoneum, which may decrease the likelihood of injuring the bladder.

Selective dissection of the ureter is favored over routine dissection. Dissection of the pelvic sidewall and ureterolysis is prudent when there is scarring or significant distortion of the anatomy. Routine dissection by less experienced surgeons may result in bleeding, which further obscures anatomy and tissue planes. Extensive dissection of the ureter near the cervix, in an attempt to isolate it from the uterine artery, can result in devascularization and necrosis.

Postoperative ureteral stent placement should be considered when aggressive ureterolysis is required, because it can result in ischemia with scarring and stricturing.

Preoperative ureteral stenting has not been shown to result in a statistically significant decrease in ureteral injury rate[16,17] and is not cost-effective at common levels of injury. When there is significant distortion of anatomy, ureteral stents may be placed to aid in identification of the course of the ureter. As an alternative, indocyanine green can be injected into the ureters through the tip of a ureteral catheter. It fluoresces at 830 nm in response to a near-infrared laser. The light is then captured and displayed, allowing for visualization of the ureter.[18] The Firefly Fluorescence Endoscopic system is integrated into the da Vinci Si and Xi surgical robots and does not require any additional equipment.

Accidental transection of the ureter can be avoided at the level of the infundibulopelvic ligament by creating a window in the medial leaf of the broad ligament. The peritoneum of the lateral pelvic sidewall is incised lateral to the ovarian vessels. The ureter is identified in the avascular pararectal space. The ovarian vessels are isolated, and a window is made in the medial leaf of the broad ligament, above the ureter.

Whether applied intentionally or unintentionally, all energy sources are inherently dangerous to viscera and vasculature. Several comparative studies between bipolar and ultrasonic devices demonstrated less than 3 mm of coagulative necrosis for all instrumentation.[19–22] Establishing a 5-mm margin between application of a device and vulnerable structures will prevent delayed injuries. This is particularly important to the ureter at the level of the uterine and ovarian vessels. All laparoscopic energy sources create a rise in temperature at the tip that is above the "cell kill" threshold.[23] Application of an instrument to any of the urogenital structures should be delayed until there has been sufficient time to cool.

RECOGNITION OF UROLOGIC INJURIES

Intraoperative Recognition

Intraoperative recognition and primary repair of injuries decrease the rate of secondary surgical procedures as well as the potential morbidity from sequelae of genitourinary tract injury. Only 14% of bladder injuries detected at the time of surgery require a major change in surgical route, but when the diagnosis is delayed, 84% require a secondary operative procedure.[15] Ureteral injuries are disproportionately diagnosed postoperatively, with more than 60% requiring a secondary surgical procedure. Most urogenital fistulae are the result of unrecognized injuries to the urogenital tract at the time of surgery. Intraoperative recognition is therefore preferred.

Cystoscopy should be performed under conditions where there may be injury to the urethra or bladder or ureteral patency may be compromised. We therefore recommend routine cystourethroscopy for all prolapse and incontinence procedures that have a relatively high risk of injury to the genitourinary tract (1–2%), including tension-free vaginal tape placement, Burch colposuspension, and high-uterosacral ligament vaginal vault suspension. McCall culdoplasty, advanced vaginal and laparoscopic procedures, and difficult abdominal procedures may also benefit from the use of cystourethroscopy. Consideration of one's own complication rate and the difficulty of an individual procedure should inform the practitioner's decision to perform cystoscopy.

After sling and other retropubic procedures, cystourethroscopy should be performed to assure the absence of mesh material in the bladder or urethra. The most typical location for injury is in the dome of the bladder, which is why it is particularly helpful to visualize the path of the trocar needles along the lateral aspect of the dome. This can be done by manipulating the needle and observing its course with a 70° cystoscope. Injury to the trigone is uncommon with midurethral slings, particularly tension-free vaginal tape. Rarely, there may be an injury to the urethra, which is best evaluated with a 0° cystoscope.

Bladder integrity can be assessed by distending the bladder with methylene blue, sterile milk, or saline. Carbon dioxide can similarly be instilled using the insufflation tubing that establishes pneumoperitoneum.[24] Distension of the bladder should be performed under direct laparoscopic guidance, generally with instillation of 200–250 mL liquid or gas. This approach is most appropriate when cystoscopy is not anticipated. Alternatively, cystoscopy may be used to evaluate the bladder when an assessment of ureteral patency is already planned. This approach also allows for localization of an injury and assesses proximity to the trigone. The bladder and ureteral orifices are best evaluated with a 70° or 30° scope.

Ureteral patency is confirmed by direct visualization of ureteral efflux on cystoscopy. Partial ligations or lacerations may not be identified, because ureteral jetting may still occur. Intravenous indigo carmine can aid in the visualization of ureteral jetting. Given recent shortages, alternatives to indigo carmine include administration of 25 mg 10% sodium fluorescein intraoperatively[25] or 100–200 mg oral phenazopyridine preoperatively.[26] When ureteral jets are

sluggish or absent, stent placement should then be attempted. If stent placement is difficult, retrograde pyelography can be performed to localize obstruction or transection.

When Urologic Consultation Is Appropriate

If an injury is suspected, but not identified intraoperatively, the investigation should be continued until a definitive conclusion has been reached, and this may require additional expertise. A high level of suspicion requires confirmation of the presence or absence of an injury followed by appropriate management. Failure to seek expert assistance may result in inappropriate treatment or additional operative procedures.

With the typical skill set of an obstetrician–gynecologist (ob-gyn), a ureteral injury is usually more difficult to detect and localize than a bladder injury. In a study that specifically reviewed the role of urologists in the management of urologic injuries, consultation was sought in 98 of more than 13,000 obstetric and gynecologic procedures.[27] There were 32 bladder injuries, with 28 diagnosed by an ob-gyn and the remainder diagnosed by a urologist. There were 11 ureteral injuries, with only one diagnosed by the operating ob-gyn. Because many gynecologists do not perform ureteral stenting or retrograde pyelography, it is not surprising that a urologist ultimately identified the vast majority of ureteral injuries in this study.

It is also appropriate to seek urologic consultation when there has been an injury to the trigone of the bladder. Proximity to the ureters is important when considering repair of the bladder trigone, and ureteral reimplantation may be required. Furthermore, consideration of the final position of the ureteral orifice is typically out of the scope of a general ob-gyn.

Figure 1 shows a practical approach to diagnosing and localizing urinary tract injuries intraoperatively.

Immediate Postoperative Recognition

Injuries that result in urinary ascites will present early in the postoperative course. Symptoms encountered with urinary tract injuries are detailed in Box 2, but profuse abdominal drain output or leakage from a wound should raise suspicion of either a cystotomy or ureteral defect. Uncommonly, extensive cellulitis[28] or even necrotizing fasciitis[29] can arise in the setting of an unrecognized urinary tract injury and a concomitant urinary tract infection.

Intravesical and intraureteral mesh from perforation will also present early in the postoperative course,

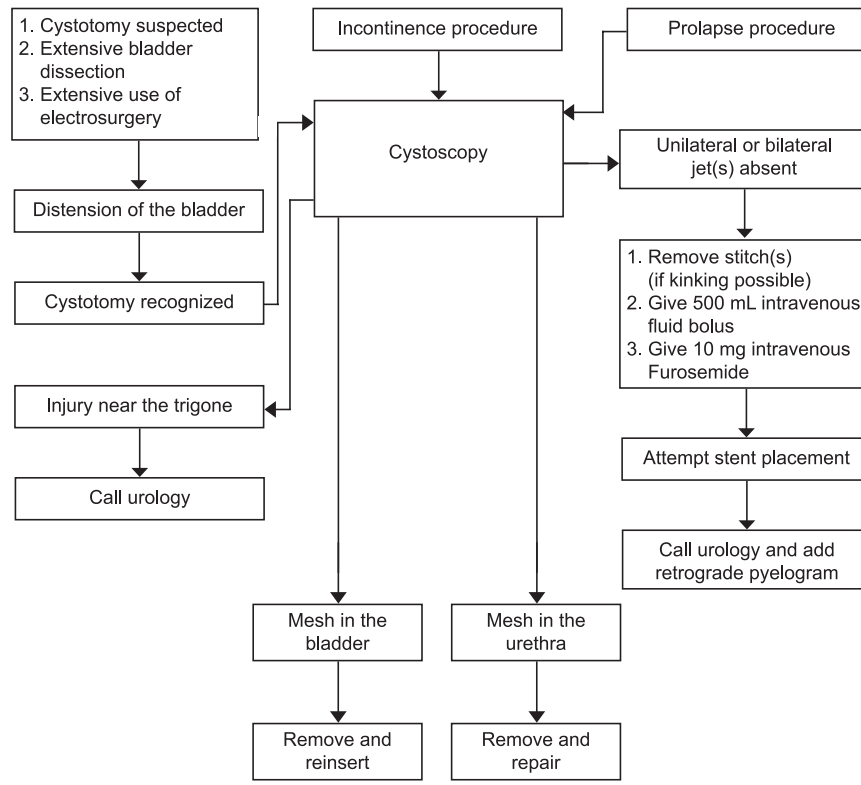

Fig. 1. Flowchart demonstrating a practical approach to the intraoperative recognition and localization of urinary tract injuries.

Sharp. Urologic Injuries in Gynecologic Surgery. Obstet Gynecol 2016.

Box 2. Symptoms of Urologic Injuries

Cystotomy or ureteral defect

- Profuse drain output
- Profuse wound leakage
- Ileus
- Fever
- Peritonitis
- Hematuria

Ureteral obstruction

- Flank or abdominal pain
- Anuria

Fistula formation

- Urinary incontinence
- Watery vaginal discharge

Intraureteral or intravesicle mesh

- Hematuria
- Dysuria
- Recurrent urinary tract infection
- De novo urinary urgency
- Urge incontinence
- Pelvic pain

Fig. 2. Computed tomography cystogram demonstrating a posterior bladder wall defect (*arrow*) with vesicovaginal fistula formation after cystotomy at the time of cesarean hysterectomy.

Sharp. Urologic Injuries in Gynecologic Surgery. Obstet Gynecol 2016.

typically with hematuria, dysfunctional voiding, and pain. De novo urgency and new-onset urge incontinence should raise suspicion about injury, especially when pain medication and anticholinergics have failed. Recurrent urinary tract infections may also develop over time.

Cystography provides information on the integrity and contour of the bladder and is useful in identifying a cystotomy. A computed tomography (CT) cystogram is the addition of retrograde instillation of radiocontrast material into the bladder to detect extravasation at the time of CT scan (Fig. 2). Conventional cystography is ideal for confirming a defect in the bladder, but CT cystography is helpful when the location of injury is less certain. Ultrasonography is the least specific study but may be helpful in identifying the need for additional imaging. Hydronephrosis and absent bilateral ureteral jets are suggestive of ureteral obstruction (Fig. 3).

Delayed Postoperative Recognition

Unilateral ureteral obstruction and fistula formation will usually present later in the postoperative course. Ureteral obstruction may cause abdominal or flank pain or may be asymptomatic, resulting in later diagnosis of a nonfunctioning kidney. Fistula formation typically results in urinary incontinence, watery vaginal discharge, or both.

Urography (or pyelography) provides information on the structure and functionality of the urinary system and is particularly helpful in identifying ureteral stricture or obstruction. The absence of contrast media within the renal pelvis at the time of intravenous pyelography is concerning for a nonfunctioning kidney. Intravenous pyelography may be combined with CT or magnetic resonance imaging for additional information and is now considered the standard for evaluation of stricture or obstruction. Retrograde pyelography is performed in conjunction with cystoscopy, because contrast media is injected directly into the ureter to assess for stricture or obstruction (Fig. 4). A combination of CT intravenous pyelography and retrograde pyelography may be necessary to appreciate the full extent of an obstruction or stricture.

Figure 5 shows a practical approach to diagnosing and localizing urinary tract injuries postoperatively. Bladder injuries can be identified with conventional or CT cystography.[30] Ureteral injury may be suspected based on renal, pelvic, and bladder ultrasonography and then localized with CT intravenous pyelography.[31] Retrograde pyelography is most helpful when CT intravenous pyelography results are inconclusive.[32]

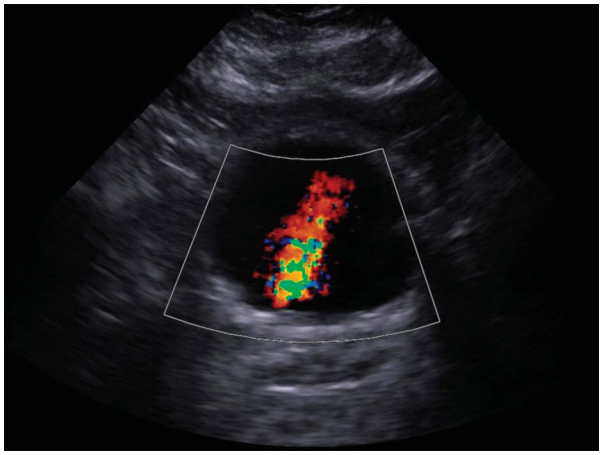

Fig. 3. Abdominal ultrasonogram of the bladder using color flow Doppler to demonstrate ureteral jetting.

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Evaluation of Fistulae

The presence of a fistula should be suspected based on urinary pattern alterations and confirmed with a combination of office examination, imaging, and possibly cystoscopy. Fistulae of the urogenital tract include communication between the vagina and the urethra (urethrovaginal), bladder (vesicovaginal), and ureter (ureterovaginal). Fistulae may be complex, involving multiple urinary structures or multiple tracts.

Urethrovaginal fistulae are uncommon complications of gynecologic surgery and should be referred to urology for repair. They may be observed on a split speculum examination, where new fistulae are often found within a patch of granulation tissue. In some cases, a small opening may be present. The presence and location of a urethrovaginal fistula may be confirmed on cystoscopy before referral.

Total urinary incontinence is commonly observed with vesicovaginal fistula,[33] and an in-office dye test can aid in confirmation. Dilute indigo carmine or methylene blue is instilled in the bladder through a urinary catheter, and a tampon is immediately placed. Coughing or performing a Valsalva maneuver before removing the tampon can aid in obtaining a positive result when a fistula is present. The presence of blue dye on the tampon is consistent with a vesicovaginal fistula. Cystoscopy should then be performed to document the location and number of fistulous tracts.

Normal voiding with continual vaginal leakage is commonly observed with ureterovaginal fistula.[33] A similar in-office dye test can be used to confirm the presence of a ureterovaginal fistula or to distinguish it from a vesicovaginal fistula. Oral phenazopyridine is administered several hours before the study. After emptying the bladder, dilute indigo carmine or methylene blue is instilled, and a tampon is placed in the vagina. The presence of orange dye on a tampon is consistent with a ureterovaginal fistula, whereas blue dye is consistent with a vesicovaginal fistula. Ureterovaginal fistulae should be evaluated with intravenous pyelography. Small fistulae or those in close approximation to the trigone may be missed and necessitate magnetic resonance imaging with contrast for localization.[33]

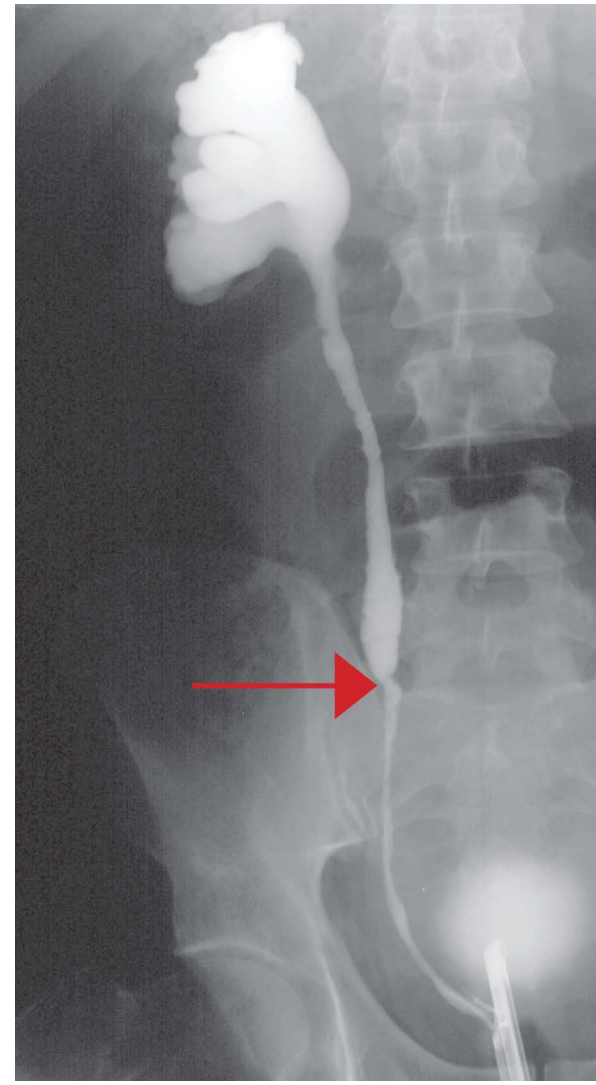

Fig. 4. Retrograde pyelogram demonstrating a ureteral stricture (*arrow*) after abdominal hysterectomy and oophorectomy.

Sharp. Urologic Injuries in Gynecologic Surgery. Obstet Gynecol 2016.

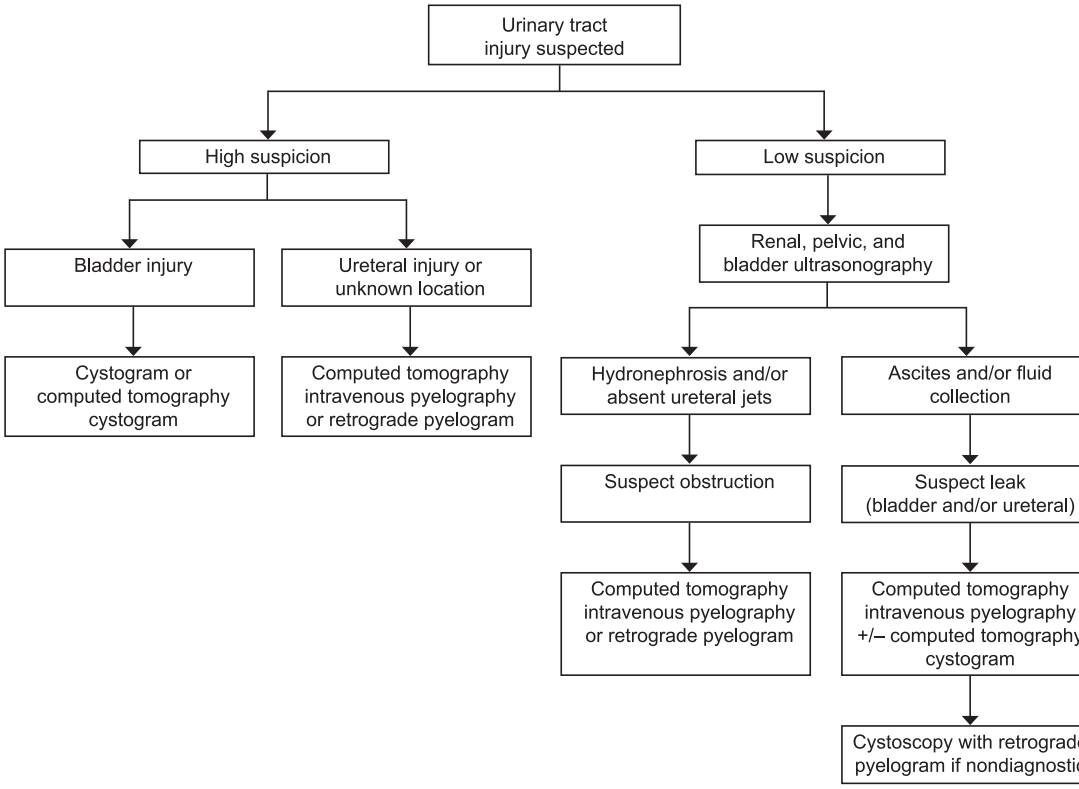

Fig. 5. Flowchart demonstrating a practical approach to the postoperative recognition and localization of urinary tract injuries.

Sharp. Urologic Injuries in Gynecologic Surgery. Obstet Gynecol 2016.

TREATMENT OF UROLOGIC INJURIES

Intraoperative Treatment

Primary repair at the time of initial surgery becomes the most important task when injury cannot be avoided. Failure to recognize and treat an intraoperative injury will inevitably lead to morbidity and often requires reoperation.

Urethral Injuries

Simple laceration of the urethra at the time of suburethral dissection can be repaired primarily in two layers with delayed absorbable suture. This should be followed by Foley catheter drainage for 7 days. Injury to the urethra as a result of injury to the trigone should involve a urologist or a gynecologist with advanced training in urologic repair.

Bladder Injuries

Injuries to the bladder dome that are less than 2 mm do not require repair or prolonged catheter drainage. This includes bladder perforation at the time of retropubic sling placement.[34] In the event that a trocar perforates the bladder, the offending mesh arm should be removed, replaced, and correct positioning confirmed with repeat cystourethroscopy. No further treatment is necessary. There appears to be no difference in postoperative complications or success rates when correctly replaced.[35]

Injuries to the bladder dome that are greater than 2 mm are repaired based on their size and are defined as less than 1, 1–2, and greater than 2 cm. Injuries greater than 2 mm but less than 1 cm can be managed expectantly with Foley catheter drainage for up to 7 days. Cystotomies between 1 and 2 cm can be repaired with a single layer of delayed absorbable suture. Cystotomies greater than 2 cm are repaired in a two-layered running closure using a delayed absorbable suture. Multiple small cystotomies in close approximation may be connected and repaired as a single larger cystotomy.

Injuries to the trigone may occur with concomitant injuries to the urethra and ureters as a result of the posterior location of the ureteral ostia and urethrovesical junction. Exposure to the injury may be difficult to achieve, and ultimately, ureteral and urethral integrity must be assessed. Repair of these injuries should involve a urologist or a gynecologist with advanced training in this type of urologic repair.

Foley catheter drainage should be carried out for 5–14 days after cystotomy repair. The duration depends on the extent of injury.[30] Additional consideration may be given to extending catheter drainage after cystotomy repair in patients who have previously undergone pelvic radiation or are immunosuppressed.

Cystography does not appear necessary before catheter removal after closure of a simple defect of the dome and prolonged drainage, because leaks are rarely observed. In contrast, it is important to assess for leakage after repair of a complex injury, as defined by involving the trigone or requiring ureteral reimplantation.[36] Time to bladder healing varies, so, if an injury measuring 3–9 mm is treated conservatively with catheter drainage alone, cystography should be performed to investigate bladder integrity before catheter removal.

Ureteral Injuries

There are multiple types of injury to the ureter, including kinking, ligation, crush injury, laceration, complete transection, thermal damage, and ischemic injury. The repair required for injuries discovered during surgery depends on the type and extent of injury.

Kinking, ligation, and crush injuries result in obstruction to the flow of urine and may damage a segment of the ureter. Kinking can often be resolved by simple removal of a suture and requires no further management. Ligation and crush injuries can result in ureteric damage and devascularization. Ureteral stenting may be sufficient for minor damage, whereas resection may be required for more extensive damage. Crush injuries can result in a significant amount of tissue damage depending on the size, type, and duration of clamp placement. The decision to stent or resect should take those variables into account.

Lacerations can be repaired with interrupted stitches, repaired as a complete transection with reanastomosis, or reimplanted into the bladder. A laceration less than half the diameter of the ureter can be repaired over a stent with interrupted delayed absorbable suture. Injury to more than half the diameter of the ureter requires either anastomosis or reimplantation. Stent placement is used in all of these scenarios to promote ureteral healing, prevent urine extravasation, and to avoid stricturing. A ureteric stent should therefore be placed when reimplanting the ureter or reestablishing continuity.[37] A drain should also be placed in proximity to the anastomotic site to inform the health care provider of leakage.[37]

When planning repair of a complete transection, the location of the injury needs to be considered. The ureter is divided into proximal, middle, and distal thirds. The proximal portion of the ureter extends from the ureteropelvic junction to the upper border of the sacroiliac joint, whereas the middle portion extends from the upper border to the lower border of the sacroiliac joint, and the distal portion extends from the inferior border of the sacroiliac joint to the ureterovesical junction.

Injuries to the distal third of the ureter are typically managed by reimplantation, especially when in close approximation to the bladder where a ureteral anastomosis would be technically challenging. If there has not been extensive dissection of the ureter, and the vascular supply has not been compromised, a ureteroureterostomy (anastomosis) can be performed. When there is tension on the repair, a psoas hitch can usually be performed to reduce repair site tension. Injury to the middle and upper third of the ureter is managed by primary anastomosis or reimplantation with a Boari flap. Much like a psoas hitch, a Boari flap brings the bladder closer to the site of the ureteral repair to decrease tension. If additional ureter length is still required, the kidney can be mobilized.

Thermal injury or ischemia to the ureter from adventitial dissection can result in scar tissue formation and stricture or obstruction. Minor thermal injuries may be managed by ureteral stent placement. Extensive injury should be managed with resection and reparative surgery commensurate with the location of the injury. If there is a vaginal incision or a concomitant injury to the bowel in close proximity to a ureteral repair, this can result in fistula formation or anastomosis breakdown. A flap of omentum can be interposed to help avoid these complications[32] and is particularly important when thermal or ischemic injuries occur.

Maintaining adequate drainage of the urinary system with a Foley catheter and a ureteral stent is critically important to the healing of ureteral injuries. When the ureter is reimplanted, a Foley catheter should be used to maintain bladder drainage.[37] It may be removed 1–2 weeks postoperatively on cystogram confirmation of absence of a leak.[38,39] Ureteric stents after anastomosis or reimplantation may be removed 1–2 months postoperatively. Stent removal should be directly followed by either cystogram or intravenous pyelography to assess the anastomotic site.[39] At 3–6 months, and again at 12 months, the anastomotic site should be reassessed for stricture and appropriate kidney function confirmed.[38–40] This can be done with a combination of intravenous pyelography, renal ultrasonography, and serum creatinine.[38–40]

Postoperative Treatment

Some injuries discovered postoperatively can be managed through drainage techniques, whereas others will require a return to the operating room. When there is obstruction to the flow of urine from the kidney, the first priority is to either restore or divert flow to avoid long-term renal damage. This is particularly important when a pelvic infection or abscess is present, because repair will need to be delayed until the infection has been treated. In the absence of infection, reoperation may be undertaken immediately after diagnosis, when operative management is deemed appropriate.[38,41–44]

Urethral Injuries

Postoperatively detected urethral injuries usually present as urethrovaginal fistulae and should be repaired as such, using urologic expertise when nonresponsive to Foley catheter drainage.

Bladder Injuries

A small defect in the bladder, measuring less than 1 cm, may be treated with Foley catheter drainage as is the case with small intraoperatively discovered cystotomies. Drainage should be maintained for 7 days, and a cystogram should be performed before removal. Larger cystotomies require reoperation and can use the vaginal, laparoscopic, or abdominal approach as appropriate, depending on the surgeon's training.

Ureteral Injuries

If ligation is identified postoperatively and thought to be the result of an absorbable suture entrapping the ureter, a percutaneous nephrostomy tube can be used for diversion while the suture absorbs. Ureteral strictures that are diagnosed early and are relatively short (less than 2 cm) can be managed by stenting and other endourologic procedures such as anterograde dilation and incision.[45] Surgical excision and repair is generally required when endoscopic measures fail, the stricture is discovered late, or there is a large segment of ureter involved. Postoperative repair follows the same principles and techniques as described in the section on "Intraoperative Treatment of Ureteral Injuries."

Secondary leaks after a primary repair should be managed with percutaneous nephrostomy tube drainage and anterograde ureteral stents when possible, because retrograde stenting is often unsuccessful. Urinomas can be managed with percutaneous drain placement.[32] Ureteral stents are not without complication and even correctly placed stents can be accompanied by irritative voiding symptoms, flank pain, suprapubic discomfort, and hematuria. More severe complications can result from stenting-induced trauma and include ureteral and parenchymal perforation with associated hemorrhage.

Urogenital Fistulae

Urogenital fistulae do not have to be immediately repaired at the time of diagnosis, because they may spontaneously resolve with drainage and diversion techniques. Foley catheter drainage should be the primary treatment of urethrovesical and vesicovaginal fistulae, especially because waiting 6–12 weeks postoperatively for granulation tissue to resolve will improve the chance of a successful repair. Similarly, stenting should be the primary treatment for ureteric fistulae, reserving ureteroureterostomy and ureteroneocystostomy for drainage and diversion failures.[32]

When Foley catheter drainage or ureteral stenting does not resolve fistulae, surgical management is the appropriate next step. Patients with urethrovesical fistulae should be referred to urology, whereas vesicovaginal fistulae can be treated by a urogynecologist, a gynecologic oncologist, or a general gynecologist with advanced training in urologic repair. For vesicovaginal fistulae, the epithelium around the fistula is incised, the surrounding tissue is mobilized, the fistulous tract is excised, and the defect is closed in several layers of delayed absorbable suture. A watertight bladder repair should be confirmed, and an attempt should be made to avoid overlapping the bladder suture line with the vaginal and endopelvic fascia suture line. If the fistula is near the trigone, cystoscopy should be performed to ensure bilateral ureteral patency. Ureterovaginal fistulae are most commonly treated with ureteral reimplantation and ligation of the distal portion of the ureter near the fistula. This can be accomplished laparoscopically or abdominally, depending on the treating physician's training.

CONCLUSIONS

Injury to the urinary tract is a known complication associated with gynecologic surgery. Gynecologic surgeons should understand the anatomy of the urinary tract to minimize the risk of surgical injury. Even in the most skilled of hands, injury may occur as a result of anatomic variation, scarring, and pelvic pathology within the urologic and reproductive systems. It is preferable to recognize urologic injury intraoperatively; however, this can be difficult and not always possible. Early recognition may decrease subsequent morbidity, which tends to be directly related to the amount of delay.

Treatment of urinary tract injury should be performed by a surgeon familiar with the type of injury incurred. If a gynecologic surgeon is not well-versed in such an injury, a urologic surgeon or surgeon with advanced urologic experience should be consulted.

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