Prevention of ureteral injuries in gynecologic surgery

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Pelvic surgery is the most common cause of iatrogenic ureteral injury. The majority of patients with ureteral injuries have no identifiable predisposing risk factors. A simple maneuver that has been taught successfully at our institution that facilitates the identification of the ureter is described. When injury is discovered during surgery, correction of the injury can be repaired with minimal risk of long-term sequelae. Postoperatively, patients with ureteral injury typically present with costovertebral angle tenderness, ileus, fever, and flank pain with a minimal rise in serum creatinine. To prevent ureteral injuries, the surgeon must have a thorough knowledge of the location of the ureter during various pelvic procedures and the specific regions where it is most susceptible to injury. (Am J Obstet Gynecol 2003;188:1273-7.)

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Ureteral injury is not uncommon in pelvic surgery. In fact, 75% of all ureteral injuries occur during gynecologic surgery, with the majority of these injuries occurring during abdominal procedures.1 Previous studies have reported a 0.4% to 2.5% rate of injury during benign pelvic surgery and only a third of these injuries were recognized at the time of surgery.2 Consequently, the actual incidence of intraoperative ureteral trauma can be much higher. Even though the risk of injury is significantly higher in surgeries involving invasive cancer and urogynecologic procedures, all pelvic surgeons must become familiar with the causes and risk factors associated with this preventable complication. In this article, we reviewed the anatomic considerations, etiologic factors, risk factors, clinical presentation, prevention, and management of ureteral injuries sustained during pelvic surgery.

Anatomic considerations

To prevent injury to the ureter, the pelvic surgeon must become familiar with the anatomic features of the ureter and areas where it is most susceptible to trauma. Ureters are retroperitoneal tubular structures measuring approximately 25 to 30 cm in length, extending from the renal pelvis to the urinary bladder.1,3,5 The right ureter is approximately 1 cm greater in length than the left ureter. The abdominal portion of the ureter lies on the anterior surface of the psoas muscle, descending posterolaterally as it crosses over the iliac vessels. The right ureter contacts the descending portion of the duodenum anteriorly, running along the right aspect of the inferior vena cava. The left ureter lies posterior to the left colic vessels and passes posterior to the mesentery of the sigmoid colon. As the ureter approaches the pelvis, it is crossed anteriorly by ovarian vessels. The right ureter enters the pelvis by crossing over the external iliac artery while the left ureter crosses over the common iliac artery. At this point, the ureter lies medial to the branches of the anterior division of the hypogastric artery and lateral to the peritoneum of the cul-de-sac. At the midplane of the pelvis, the ureter is crossed anteriorly by the uterine artery. Here it tunnels into the cardinal ligament, approximately 1.5 to 2.0 cm lateral to the cervix near the internal cervical os and vaginal fornices as it enters into the trigone of the bladder.3 Histologically, the ureter is composed of three concentric layers that include an inner layer composed of transitional epithelium, a middle layer of circular and smooth muscle, and an outer layer of adventitial sheath.1,3,4 The adventitial layer contains the arterial supply, nerve supply, and lymphatics of the ureter. Thus, it is important to maintain the integrity of the adventitial sheath during dissection of the ureter. To prevent ischemic injury to the ureter, one must also become familiar with its unique blood supply. The renal artery, ovarian artery, common iliac artery, and the aorta all contribute blood supply to the ureter. In the abdomen, the ureter derives its blood supply from small arteries approaching it medially, whereas the pelvic ureter receives its blood supply from vessels approaching laterally.1,3 Because the vessels interface with the peritoneum, attempts should always be made to preserve the peritoneum with the ureter during dissection. Thus, the peritoneal incision to expose the ureter should be made laterally to the ureter in the abdomen and medially in the pelvis.
Intraoperative injury to the ureter may result from ligation, angulation, transection, laceration, crush, ischemia, and resection. The most common site of operative injuries to the ureter during routine abdominal hysterectomy or adnexectomy is at the pelvic brim, where the ureters lie beneath the insertion of the infundibulopelvic ligament. Other common locations are over the iliac arteries, within the cardinal ligament at the level of the internal cervical os where the uterine artery crosses the ureter, and at the anterolateral fornix of the vagina as the ureter enters the bladder (Fig 1). In urogynecologic procedures (ie, Marshall-Marchetti-Krantz cystourethropexy or retropubic urethropexy), ureteral injuries usually occur near the ureterovesical junction. During vaginal hysterectomy, the ureter can be traumatized near the internal cervical os and vaginal fornices as it enters into the trigone of the bladder (Fig 2). In laparoscopic surgery, particularly during ablation of endometriosis, the most common site of ureteral injury is near the uterosacral ligaments, which have become thickened as a result of endometriosis. In the obstetric patient, ureteral injury can occur as a result of suturing an extended ureteric incision in an effort to control bleeding within the broad ligament during a cesarean hysterectomy or in the process of performing a hypogastric artery ligation.

Risk factors
Although most ureteral injuries occur in patients who have no identifiable risk factors, there are certain conditions that increase the likelihood of ureteral injuries, particularly those that disrupt the normal anatomy and architecture of the ureters. These conditions include endometriosis, large ovarian masses, and pelvic inflammatory disease. Two large studies have retrospectively reviewed the incidence of ureteral injuries and its associated risk factors. These authors found that pelvic malignancies were present in 44% of the cases and appear to be a significant risk factor associated with ureteral injury. This is most likely related to the presence of tense adhesions, large masses that displace the ureter, and anatomical changes distorting the position of the ureters. Other risk factors include previous pelvic surgery, broad ligament fibroids, and history of pelvic radiation. Other less common factors that predispose a patient to ureteral injury include congenital abnormalities such as ureteral duplication, megareter, and ectopic ureter or kidney. However, it is noteworthy that half of all ureteral injuries had no identifiable predisposing factors.

Preventing ureteral injury
Abdominopelvic surgery. The best way to prevent injury to the ureter is to routinely identify its path through the pelvis and the regions where it is most susceptible to injury. A detailed illustration has been provided depicting the areas where the ureter is most susceptible to injury during abdominopelvic surgery (Fig 1). The ureter must be identified through an incision that provides adequate exposure to prevent iatrogenic injury. The peritoneum is opened lateral to the infundibulopelvic ligament, and the ureter is identified on the medial leaf of the peritoneum. A simple maneuver described by Manetta et al11 that facilitates the identification of the ureter involves the following steps. After dividing the round ligament near the lateral pelvic sidewall, the lateral peritoneum is opened 10 to 15 cm in a cephalad direction. An index finger is then placed on the external iliac artery, which can be identified easily from its superficial, consistent anatomic position and pulsating characteristics. If one then moves their finger upward (cephalad), the first structure to be exposed, crossing and in contact with the iliac artery, will be the ureter. As the surgeon places an index finger on the ureter, the infundibulopelvic ligament should be behind the middle phalanx. In this manner, the infundibulopelvic ligament can be safely clamped with the ureter under direct visualization. The ureter is subsequently followed toward the cardinal ligament, where it passes under the uterine artery. If one needs to dissect the ureter away from harm, it is important to preserve the normal blood supply to the segment of the ureter found in the lower pelvis or on the level of the intravesical wall. Stallworthy12 recommends preservation of the mesentery to the ureter by carefully dissecting the ureter from the pelvic wall location while preserving its attachment medially to the peritoneum. This thin mesentery of fibrofatty tissue and small blood vessels contributes to the ureteral blood supply by branches from the hypogastric. Although dissection or mobilization of the ureters may not be indicated, the ureters should be clearly identified in the abdomen or pelvis, particularly in areas where it is most susceptible to injury. To distinguish the ureter from other vascular structures, the ureter will typically elicit peristalsis on gentle stroking. Others have observed that the ureter has a characteristic snap when it is gently palpated. Previous studies have revealed that attention to the anatomic course of the ureter during pelvic surgery is more effective in preventing injury than preoperative intravenous pyelograms (IVP) or ureteral stent placements. Although its usefulness is debatable, IVPs have been used preoperatively to locate the ureters for surgery in patients with disease processes that may distort the ureters, such as pelvic masses or inflammatory disease. In a study of 493 patients undergoing vaginal and abdominal hysterectomies, Piscitelli et al10 found that preoperative abnormal IVP findings to be associated with patients who had an enlarged uterus ≥12 weeks' gestational age or ovarian masses ≥4 cm or greater. On the other hand, incidence of abnormal IVP findings was not increased in patients with endometriosis, pelvic inflammatory disease, pelvic relaxation, or a history of previous pelvic surgery. Most impor-
tantly, preoperative IVPs did not decrease the incidence of ureteral injuries.\textsuperscript{16} Retrograde ureteral catheters, which are used to help identify ureters for dissection, were also found to have questionable value in the prevention of intraoperative ureteral injury. In a review of 3071 major gynecologic surgeries, in which 15\% underwent bilateral prophylactic ureteral catheterization, Kuno et al\textsuperscript{14} found that prophylactic ureteral catheterization did not eliminate the risk of ureteral injuries. Clearly, the best defense against ureteral injury is meticulous surgical technique and identifying the course of the ureter and the associated anatomic locations where injury is most likely to occur.

During abdominal hysterectomy, the ureter can be visualized by opening the anterior leaf of the broad ligament. The ureter is surrounded by loose avascular fibroconnective tissue. Once exposed, the ureter is gently pushed laterally and downward, moving it away from the cervix. This maneuver protects the ureter and with traction on the uterus also exposes the uterine artery. However, endometriosis and/or pelvic inflammatory disease may disfigure the region where the ureter crosses the uterine artery at the midplane of the pelvis. Furthermore, large broad ligament or cervical leiomyomas may obscure the operative field, making the dissection extremely difficult.

\textbf{Vaginal surgery.} A detailed figure has been provided depicting the areas where the ureter is most susceptible to injury during vaginal surgery (Fig 2). During vaginal hysterectomy or surgery for pelvic floor relaxation, one must develop an adequate vesicouterine space to protect the ureters from injury by surgical clamps and sutures. This is achieved by downward traction on the cervix and countertraction upward beneath the bladder. It is important to clamp, cut, and ligate only small bites of paracervical and parametrial tissue adjacent to the uterus. These steps are critical to ensure that the ureters stay safely away

\textbf{Fig 1.} Ureteral injury in abdominopelvic surgery.
from the operative field. The ureters can be palpated by applying gentle traction on the cervix, combined with upward traction on the upper vagina exposing the entry point of the ureter into the trigone.

**Anterior colporrhaphy.** During anterior colporrhaphy, the surgeon must be careful not to start too laterally or to insert the sutures too deeply to prevent needle injury to the ureters while plicating the bladder. In fact, Hofmeister found that the distance between the ureter and the surgeon’s needle in the upper third of the vagina is only 0.9 cm during anterior colporrhaphy using fluoroscopic imaging.

**Intraoperative diagnosis of ureteral injury.** If ureteral injury is suspected intraoperatively, the surgeon must promptly identify the ureter and evaluate the severity and nature of the injury. If the injury cannot be adequately visualized, an intravenous injection of indigo carmine can help confirm and identify the location of the ureteral injury. If urine passed into the Foley catheter is blue, one
A urinoma may develop, which can become infected and result in extravasation of urine into periureteral tissues. Segments of ureters can lead to a weakened ureteral wall, particularly without any long-term sequelae. However, necrosed segments of ureters can be repaired by an end-to-end anastomosis.\(^1\,7\) To ensure ureteral patency, partial transections are typically corrected by suture repair or resection of the affected segment. Clearly, damage to a greater portion of the ureter requires a more involved repair. A crush injury or transection in the middle portion of the ureter can be reversed intraoperatively without any long-term sequelae. However, necrosed segments of ureters can lead to an abscess. Alternatively, urine can accumulate in the peritoneal cavity leading to urinary ascites and peritonitis.\(^7\) Last, as a result of injuries during vaginal surgery, ureterovaginal fistulas may develop. Uremia typically results from damage to both ureters. Bilateral ureteral ligation presents as anuria during the first 24 to 48 hours in the postoperative period and later develop a rise in blood urea nitrogen and creatinine levels. Immediate urinary drainage, through nephrostomies, may be necessary to reestablish normal renal function.

**Practical treatment of ureteral injury**

The approach to ureteral repair depends on the cause, location, and extent of the injury. A detailed flowchart on the clinical management of ureteral injury has been provided in Fig 3. Minor trauma, such as ligature or crush injuries may be managed with stent placement and drainage of the affected area. Stents remain in place for approximately 6 weeks, followed by an IVP to ensure ureteral patency. Partial transections are typically corrected by suture repair or resection of the affected segment. Clearly, damage to a greater portion of the ureter requires a more involved repair. A crush injury or transection in the middle portion of the ureter can be repaired by an end-to-end anastomosis.\(^1\,7\) To ensure a tension-free anastomosis, it may be necessary to free the ureter from its peritoneal attachments or by mobilizing the kidney. Also, a psoas hitch can add several centimeters of length to the ureter. In this procedure, the bladder is sewn to the psoas tendon and the ureter is reimplanted through a submucosal tunnel into the bladder. Injuries near the bladder can be repaired by direct implantation of the ureter into the bladder or through a submucosal tunnel; the latter technique is less likely to be associated with vesicoureteral reflux. Injuries in the middle or upper third of the ureter can be repaired by a ureteroureterostomy, where a bridge between the ureter and the bladder is made from a segment of the terminal ileum.

**Outcomes of ureteral injury**

Minor injuries to the ureter can be reversed intraoperatively without any long-term sequelae. However, necrosed segments of ureters can lead to a weakened ureteral wall, resulting in extravasation of urine into periureteral tissues. A urinoma may develop, which can become infected and lead to an abscess. Alternatively, urine can accumulate in the peritoneal cavity leading to urinary ascites and peritonitis.\(^7\) Last, as a result of injuries during vaginal surgery, ureterovaginal fistulas may develop. Uremia typically results from damage to both ureters. Bilateral ureteral ligation presents as anuria during the first 24 to 48 hours in the postoperative period and later develop a rise in blood urea nitrogen and creatinine levels. Immediate urinary drainage, through nephrostomies, may be necessary to reestablish normal renal function.

**Comment**

The majority ureteral injuries are associated with pelvic surgery. The gynecologic surgeon must become familiar with the anatomy of the abdominal and pelvic ureter and the locations where it is most susceptible to injury. Clearly, prevention is the best defense against ureteral trauma.