Ureteral Injury

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INTRODUCTION

Ureteral injuries may be due to external trauma (blunt or penetrating) or may be iatrogenic. Traumatic injury to the ureter in civilian life is uncommon, occurring in less than 1% of urogenital injuries in major series. The incidence of traumatic ureteral injury appears to be slightly higher (6%–8%) in war-related trauma. The low incidence of traumatic ureteral injury is likely attributed to the narrow structure of the ureter, which is relatively pliable when subject to shearing, and its location deep within the abdomen, where it is protected from penetrating injury to some extent by the bony pelvis and the vertebral column.

The incidence of iatrogenic ureteral trauma is likely underestimated. Although iatrogenic ureteral injury is rare, estimates suggest that 80% of acute ureteral damage is caused by intraoperative injury. Diagnosis of iatrogenic ureteral injury is often delayed. Thus, the clinician must maintain a high index of suspicion for ureteral injury and assess for signs in the postoperative period, such as abdominal pain, tenderness, and fever. Selzman and Spirnak reviewed the charts of all patients diagnosed with iatrogenic ureteral injury between 1972 and 1992. Up to 67% of nonurologic ureteral injuries had delayed diagnosis, at an average of 65 days after surgery. Twenty of these injuries were fistulas, 24 were strictures, 14 were ligations, and 6 were urinomas. The urologic injuries were more often noted intraoperatively (77% of cases).

The American Association for the Surgery of Trauma (AAST) has produced a scoring system for ureteral injury (Table 1); however, it has not achieved the general use and recognition of the AAST scale for renal injury. Statistical validation of the AAST scale for ureteral injury has not been performed, mostly because of the paucity of ureteral injuries. A single-center study of 57 patients over a 10-year period found a correlation between grade of injury and the number and severity of associated injuries; the study also found increasing complexity of surgical management with higher grade of injury.

ANATOMY OF THE URETER

Much of the low incidence of ureteral trauma, as well as the difficulty of diagnosing ureteral injury when it occurs, is due to the ureter’s narrow diameter as well as its deep, retroperitoneal location in the abdomen and pelvis. The ureter ranges in length from approximately 20 to 26 cm and exits the renal pelvis deep to both the renal vein and artery. The ureter passes deep to the duodenum and courses downward through the retroperitoneum, directly superficial to the psoas muscle. At approximately the level of the inferior mesenteric artery, the ureter crosses underneath both the gonadal artery and vein. As it passes the pelvic brim just inferior to the common iliac bifurcation, it crosses over the external iliac artery approximately 1 to 2 cm medial to the gonadal vessels and immediately lateral to the internal iliac artery. As the ureter descends further into the pelvis, it drops under the uterine artery and then behind the vaginal artery in the female and runs in close proximity to the inferior vesical and deferential arteries in the male. At this point, the ureter becomes invested in the obturator fascia and inserts into the posterolateral base of the bladder, forming the intramural tunnel. The ureter terminates in the bladder at the ureteral orifice.

Each ureter has anatomic associations that prove important surgically. The left ureter is associated with the descending colon and sigmoid colon and their mesenteries, whereas the right ureter is associated with right-sided structures such as the ileum, cecum, appendix, and ascending colon and their respective mesenteries. The proximity of the ureter to these organs presents the possibility of damage to the ureter during surgery on any of these structures. Specifically, the anatomic relation of the ureter to the uterus and rectum as well as to the uterine and vaginal arteries places it in a precarious situation, particularly during pelvic operations such as certain colonic resections or hysterectomy. As the ureter enters the pelvis, it courses below the ovary and fallopian tube and just lateral to the uterosacral fold, uterus, and rectum.

Surgical nomenclature divides the ureter into an abdominal segment (from the renal pelvis to the iliac
Ureteral Injury

Table 1. American Association for the Surgery of Trauma Scale for Ureteral Injury

<table>
<thead>
<tr>
<th>Grade</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Hematoma</td>
<td>Contusion or hematoma without devascularization</td>
</tr>
<tr>
<td>II</td>
<td>Laceration</td>
<td>&lt; 50% transection</td>
</tr>
<tr>
<td>III</td>
<td>Laceration</td>
<td>≥ 50% transection</td>
</tr>
<tr>
<td>IV</td>
<td>Laceration</td>
<td>Complete transection with &lt; 2 cm devascularization</td>
</tr>
<tr>
<td>V</td>
<td>Laceration</td>
<td>Avulsion with &gt; 2 cm of devascularization</td>
</tr>
</tbody>
</table>


*Advance 1 grade for bilateral injuries up to grade III.

vessels) and a pelvic segment (from the iliac vessels to the bladder). Radiographically, the ureter can be divided into 3 segments—upper, middle, and lower. The limits of the upper ureter are the renal pelvis and upper edge of the sacrum. The lower limit of the middle ureter is the lower edge of the sacrum, and the lower ureter travels from the lower edge of the sacrum to the bladder.

BLOOD SUPPLY OF THE URETER

Blood reaches the ureter through a variety of arteries. Although anatomic variation exists, the ureter typically has a rich blood supply. Blood is supplied to the upper ureter by a branch from the renal artery. The middle ureter receives blood via a branch of the gonadal artery and also the aorta. The pelvic (lower) ureter receives blood from branches of the internal iliac, superior vesical, uterine, middle rectal, vaginal, and inferior vesical arteries. Once these arteries reach the ureter, they branch into a delicate plexus that runs longitudinally along the length of the ureter within the adventitia. This plexus allows for significant mobilization of the ureter without compromise of blood supply but also represents the reason why the ureter does not tolerate removal or disruption of its adventitial layer. An important anatomic consideration is that blood supply to the abdominal segment of the ureter comes from a medial direction, whereas, in the pelvic segment, blood is supplied from the opposite direction. Venous drainage of the ureter typically mirrors the arterial anatomy (Figure 1).

INCIDENCE AND ETIOLOGY

TRAUMATIC URETERAL INJURY

Summary of available data indicates that the majority of ureteral injuries from external violence are caused by gunshot wound and are evenly distributed throughout the course of the ureter (Table 2). The ureter is rarely the only organ involved (Table 3), and associated injuries are often multiple and are usually the factors precipitating exploratory surgery. Accompanying injuries to the bowel, bladder, and kidneys are common. The serious nature of associated injuries may preclude proper evaluation of the ureter preoperatively, and the urologist must be aware of the possible course of the penetrating object (eg, knife, bullet, shrapnel) in relation to ureteral anatomy. Mortality in cases of traumatic ureteral injury is often due to the associated injuries, especially vascular trauma.
IATROGENIC URETERAL INJURY

In 1971, a report on ureteral injury found that 34 of 39 cases of iatrogenic injury (87%) were due to open surgery and 5 were secondary to endoscopic surgery. The principal signs and symptoms of ureteral injury were abdominal pain (56%), tenderness (41%), fever (31%), vaginal leakage (10%), wound leakage (10%), and abdominal mass (7%). Adynamic ileus was also frequently noted. Urinalysis was normal in 88% of patients. An older series reported on 87 cases of iatrogenic ureteral injury (16 men, 71 women). Fifty of the injuries in women occurred during abdominal hysterectomies. Overall, 69% of cases resulted from gynecologic surgery, 25% from general surgery, and the remaining 6% from urologic surgery. Ureteral injury was recognized intraoperatively in 18.4% of patients, within a month in 46% of patients, and longer than 1 month in 35.6% of patients. It is likely that the incidence of iatrogenic ureteral injury may have been underestimated in the past, as routine postoperative radiologic evaluation of the ureters was not performed in patients who were doing well clinically. This may have resulted in death in patients who were asymptomatic following apparently successful operations.

Etiology

Several studies have shown a significant increase in iatrogenic ureteral injury due to laparoscopy and ureteroscopy. In a study comparing a cohort of patients with iatrogenic ureteral injury treated from 1980–1984 with patients treated from 1985–1989, the overall risk of ureteral injury increased from 4 to 11 per 10,000 hospital admissions during the period. Of the 8 patients treated from 1980–1984, 4 injuries were gynecologic, 2 were general surgery–related, and 2 were urologic. Of 19 patients treated from 1985–1989, 9 injuries were gynecologic (2 laparoscopic) and 10 were urologic (all during ureteroscopic procedures). A similar report comparing patients diagnosed with iatrogenic ureteral injury during 1984–1992 with patients diagnosed during 1972–1983 (Table 4) found urologists to be increasingly responsible for iatrogenic ureteral trauma. More than 90% of these cases occurred in the lower third of the ureter.

Of note, the shift in etiology of iatrogenic ureteral injury occurred as the treatment of ureteral stones became principally endoscopic, but it is important to keep in mind that there were essentially no functional flexible ureteroscopes prior to 1995. Instruments have become smaller since then, and ancillary equipment such as baskets, lasers, and wires are much improved. Consequently, as seen in another study based on cases of ureteral injury from 1998–2002, the percentage of ureteral injuries caused by ureteroscopy decreased from 8% (26 of 331 cases) in 1998 to 2% (10 of 482 cases) in 2002. The majority of these injuries were relatively minor. A review of the literature on stone basketing found that the incidence of ureteral avulsion had decreased from 0.5% (5 of 941 patients) in 1987 to 0.3% (15 of 5117 patients) in 1996 and to 0% (0 of 1059 patients) in 2001. The overall ureteral stricture rate was 0.58% (total patients, 6554).

Risks with gynecologic surgery. The overall rate of ureteral injury during gynecologic surgery is extremely low. Certain maneuvers during abdominopelvic surgery, including ligation of gonadal vessels, pelvic lymph node dissection, dissection of the bladder and vagina, and ligation of ureteral vessels, place the ureter at risk for injury. Vaginal surgery also presents a risk to the ureter. The ureter is most at risk for injury during gynecologic procedures at the pelvic brim, beneath the infundibulopelvic ligaments, where it is crossed by the uterine artery, near the cervix. Injuries may result from clamps or sutures applied in the vesicouterine space during vaginal hysterectomy. During anterior colporrhaphy, injury may result from sutures placed either too lateral or too deep. During open pelvic operations, injury to the ureter occurs most commonly from ligation and crush injury. The ureter also may be partially or totally transected, partially resected, or devascularized, resulting in fistula or stricture formation.

Ischemic injury is most likely a result of injury to the adventitial layer during radical hysterectomy. During vaginal operations, injuries mostly occur at the vaginal fornices, as the ureter enters the posterior bladder wall. Gilmour et al found that laparoscopic hysterectomy posed the greatest risk to the ureter, with a rate of 13 injuries per 1000 surgeries compared with less than 1 injury per 1000 surgeries for subtotal hysterectomy with or without bilateral salpingo-oophorectomy.

Of 600,000 hysterectomies performed annually in the

Table 2. Etiology and Location of Ureteral Injury from External Trauma

<table>
<thead>
<tr>
<th>Mechanism of injury</th>
<th>Total, n</th>
<th>Gunshot, n (%)</th>
<th>Stab, n (%)</th>
<th>Blunt, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Trauma</td>
<td>293</td>
<td>243 (83)</td>
<td>27 (9)</td>
<td>23 (8)</td>
</tr>
<tr>
<td>Location of injury (third of ureter)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper</td>
<td>39%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>31%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal</td>
<td>30%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data summarized from references 11–22.
United States, ureteral injury occurs in approximately 0.02% to 2.5% of cases.33 Most data on hysterectomy-associated ureteral injury are retrospective, but a recent prospective study found 8 cases of ureteral injury in 471 patients (1.7%) undergoing hysterectomy for benign disease.34 All patients had cystoscopy at the end of the procedure, with indigo carmine given to assist in confirming efflux of urine from each ureter. Cases in which ureteral injury occurred were more difficult, at times due to concurrent prolapse surgery. Overall, ureteral injury was more likely to occur when operative time was longer and blood loss was greater. The authors concluded that routine cystoscopy after hysterectomy is worthwhile, as all ureteral injuries and 16 of 17 bladder injuries were detected intraoperatively and immediately treated.34 A review of 18 ureteral injuries from a pool of 5122 patients over 15 years showed that total abdominal hysterectomy with bilateral salpingo-oophorectomy presented a greater risk to the ureter than either vaginal or radical hysterectomy without bilateral salpingo-oophorectomy.35

Other risk factors. Although approximately half of all patients who sustain ureteral injury have no identifiable risk factors, there are some conditions that predispose the ureter to injury. Pelvic malignancy appears to be a significant risk factor for ureteral injury.32 In addition, prior radiotherapy to the pelvis and adhesions from previous operations can place the ureter at risk for injury. Endometriosis, pelvic inflammatory disease, and leiomyomas are risk factors specific to women. Less common risk factors include congenital difficulties, such as megaureter or ureteral duplication.32 Surgery for benign disease typically presents less danger to the ureter than those performed to treat malignancy.

APPROACH TO DIAGNOSIS AND MANAGEMENT

DIAGNOSIS OF TRAUMATIC URETERAL INJURY

Case 1 Presentation

A 23-year-old man is admitted to the emergency department after being involved in a truck accident. He was ejected from the vehicle and the truck rolled on him. The patient’s heart rate is 130 bpm and blood pressure is 95/65 mm Hg. His head, chest, and upper limbs show no sign of injury. The patient’s abdomen is distended, he has multiple pelvic fractures, and he has no movement in his lower limbs. A FAST scan reveals fluid in the abdomen and pelvis, presumed to be blood. Computed tomography (CT) reveals tears in the liver and spleen, along with grade IV injuries to both kidneys.

Table 3. Associated Injuries in Ureteral External Trauma

<table>
<thead>
<tr>
<th></th>
<th>Carlton et al32</th>
<th>Perez-Brayfield et al32</th>
<th>Elliott and McAninch11</th>
<th>Best et al10</th>
<th>Cass34</th>
<th>Liroff et al25</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>39</td>
<td>118</td>
<td>36</td>
<td>57</td>
<td>12</td>
<td>20</td>
<td>282</td>
</tr>
<tr>
<td>Small bowel</td>
<td>28</td>
<td>61</td>
<td>20</td>
<td>47</td>
<td>10</td>
<td>10</td>
<td>176 (62)</td>
</tr>
<tr>
<td>Colon</td>
<td>17</td>
<td>42</td>
<td>16</td>
<td>13</td>
<td>—</td>
<td>9</td>
<td>97 (34)</td>
</tr>
<tr>
<td>Vascular</td>
<td>11</td>
<td>15</td>
<td>3</td>
<td>9</td>
<td>3</td>
<td>9</td>
<td>50 (18)</td>
</tr>
<tr>
<td>Liver</td>
<td>7</td>
<td>16</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>—</td>
<td>36 (13)</td>
</tr>
<tr>
<td>Kidney</td>
<td>7</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>1</td>
<td>—</td>
<td>29 (10)</td>
</tr>
<tr>
<td>Pancreas</td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>—</td>
<td>24 (9)</td>
</tr>
<tr>
<td>Chest</td>
<td>5</td>
<td>—</td>
<td>5</td>
<td>3</td>
<td>—</td>
<td>—</td>
<td>13 (5)</td>
</tr>
<tr>
<td>Stomach</td>
<td>4</td>
<td>11</td>
<td>—</td>
<td>6</td>
<td>—</td>
<td>4</td>
<td>25 (9)</td>
</tr>
<tr>
<td>Spleen</td>
<td>1</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>—</td>
<td>3 (1)</td>
</tr>
<tr>
<td>Gallbladder</td>
<td>1</td>
<td>5</td>
<td>—</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>7 (2)</td>
</tr>
<tr>
<td>Bladder</td>
<td>1</td>
<td>6</td>
<td>—</td>
<td>4</td>
<td>—</td>
<td>—</td>
<td>11 (4)</td>
</tr>
<tr>
<td>Rectum</td>
<td>1</td>
<td>10</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>11 (4)</td>
</tr>
<tr>
<td>None</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>—</td>
<td>—</td>
<td>2</td>
<td>10 (4)</td>
</tr>
</tbody>
</table>

Table 4. Iatrogenic Ureteral Injury, 1972–1992

<table>
<thead>
<tr>
<th></th>
<th>General Surgery–Related</th>
<th>Gynecologic</th>
<th>Urologic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972–1983</td>
<td>23</td>
<td>22</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>1984–1992</td>
<td>16</td>
<td>34</td>
<td>55</td>
<td>105</td>
</tr>
</tbody>
</table>

He is resuscitated with 6 U of blood and is taken to the operating room for exploratory laparotomy.

During surgery, the patient is found to have severe splenic bleeding, prompting splenectomy. The liver is not bleeding, and there are no major vascular or intestinal injuries. A large left retroperitoneal hematoma is noted, which is not explored. Ten days postoperatively, the patient is febrile and has left abdominal tenderness. Ultrasonography reveals fluid collection in the left upper retroperitoneal area, felt possibly to be a urinoma. A retrograde pyelogram is performed (Figure 2), which reveals extensive extravasation from the upper left ureter. Attempts to pass a wire into the renal pelvis are unsuccessful.

**DISCUSSION**

Suspicion of ureteral injury must be high or the injury may be missed. Gross or microscopic hematuria is present in 75% to 85% of cases of ureteral injury. Urinalysis is only one aspect of the evaluation; therefore, knowledge about the history of the injury and its severity play a major role in deciding whether urinary tract imaging is necessary.

In many cases, diagnosis of ureteral injury is made at the time of laparotomy. It must be emphasized that ureteral injury should be suspected, and the entire course of the ureter should be explored and dissected. Clear surgical exposure must be obtained if there is any chance that a knife or bullet has gone near the ureter. This is particularly true for high-velocity missiles (in the case of war-related trauma), which may not directly injure the ureter but instead may cause delayed leakage from proximity injury.

**Imaging**

Historically, intravenous pyelography (IVP) has been the radiologic modality of choice, with a sensitivity of 60% to 91%. One-shot intraoperative IVP is less sensitive (40%). Findings suggestive of ureteral injury on IVP include delayed excretion of contrast, poor function on one side, hydronephrosis, failure to visualize the entire course of the ureter, and most importantly, extravasation of contrast material.

Rapid CT scanning is available at most trauma centers and has essentially replaced IVP in the evaluation of the urinary tract in cases of external violence. If early phase and delayed scanning is performed, the sensitivity of rapid CT is generally agreed to be close to 100%. On CT demonstrating ureteral injury, the kidney will be intact without perirenal hematoma, and contrast will be seen above the injury site in the ureter but not below. The most significant finding, as with IVP, is extravasation of contrast from the site of injury. In ureteropelvic junction injury, extravasation will usually be medial to the pelvis; injuries below this level extravasate in a circumferential, ragged fashion. Lack of contrast in the distal segment of the ureter suggests a complete transection provided that delayed CT was also performed.

Retrograde pyelography is sensitive for detecting ureteral injury but is not useful in the acute trauma situation because of its cumbersome nature. It is an excellent way of evaluating the ureter in cases in which an injury may have been initially missed and the clinical course raises suspicion of urinary leak (eg, signs such as fever, abdominal fluid collection, flank tenderness, high volume of drainage, high creatinine level, prolonged paralytic ileus). Prompt diagnosis of ureteral injury is preferable to delayed diagnosis, as the repair of injury is usually easier, there are fewer procedures involved, and the clinical course is more rapidly positive. Delayed diagnosis of ureteral injury from penetrating trauma occurs in about 9% of cases and is associated with an increased risk of complications and a poor outcome. Although it did not approach statistical significance, a meta-analysis showed a mortality rate of 6.1% in patients whose traumatic injuries included a
ureteral injury diagnosed early compared with 13.2% in those with a delayed diagnosis.\textsuperscript{38}

**Blunt Trauma**

Avulsion of the upper ureter or ureteropelvic junction from blunt trauma, as occurred in case patient 1, is unusual. One review identified 54 cases of ureteral avulsion in the literature, including 6 bilateral injuries.\textsuperscript{39} Rapid deceleration was a major factor in many injuries. The right side was involved 3 times more often than the left, for no obvious reason. There was no sexual predilection, and the ratio of children to adults was 3 to 1. The increased rate in children may be because of the increased flexibility of the child’s torso during trauma, allowing more stretching and, ultimately, avulsion of the ureter.\textsuperscript{39} A study by Mulligan et al\textsuperscript{40} emphasizes that CT scanning without excretory phase imaging is likely to miss a diagnosis of ureteral injury caused by blunt trauma, as there will be no contrast leakage on the initial rapid sequence images. Diagnosis is delayed in one third of cases, causing nephrectomy rates to be much higher.\textsuperscript{39} Kunkle et al\textsuperscript{38} reported on 40 cases of ureteral injury, including 5 cases in which diagnosis was delayed. The nephrectomy rate was 18.4% in the delayed diagnosis group as compared with 2.4% in cases in which the diagnosis was established immediately.\textsuperscript{38} Urinoma, infection, abscess, and fistula are also more common in cases with delayed diagnosis.

**Case 1 Resolution**

The patient is taken to the interventional radiology suite. A percutaneous nephrostomy tube is placed, and an antegrade pyelogram reveals disruption of the left ureter just below the ureteropelvic junction (Figure 3). The nephrostomy tube is left in place, and the patient later undergoes an elective ureteral repair.

**DIAGNOSIS OF IATROGENIC URETERAL INJURY**

As with traumatic injury to the ureter, IVP is usually diagnostic of iatrogenic ureteral injury; however, CT is performed more frequently in the early postoperative patient who is experiencing symptoms. Delayed function of the involved kidney, poor function on one side, hydronephrosis, extravasation of contrast, and the finding of a urinoma are late findings that all point to ureteral injury. For further delineation of the severity and location of an injury, retrograde pyelography may be performed.

**CASE STUDIES: IATROGENIC URETERAL INJURY**

**Case 2 Presentation**

A 57-year-old woman undergoes radical hysterectomy for carcinoma of the cervix. She does well in the initial postoperative phase, but by postoperative day 5, she develops abdominal distension, tenderness, fever, and left flank pain. A CT scan with contrast reveals a large amount of abdominal and pelvic ascites (Figure 4A) and a leak of contrast medium from the lower left ureter (Figure 4B).

**Case 3 Presentation**

A 62-year-old woman undergoes surgical repair of a pelvic organ prolapse. One month postoperatively, the patient’s serum creatinine level has risen to 1.3 mg/dL (normal, 0.6–1.2 mg/dL). An antegrade pyelogram performed at the time of percutaneous nephrostomy tube placement demonstrates right-sided hydronephrosis and hydroureter with no filling of the bladder with contrast (Figure 5).

**MANAGEMENT OF URETERAL INJURY**

There is little difference in the management of ureteral injuries from trauma or iatrogenic means, except that management of the trauma patient is more likely to be affected by the patient’s overall clinical condition and associated injuries. When caused by ureteroscopic procedures, lower grades of injury (grades I and II) are typically recognized intraoperatively and can usually be managed with ureteral stenting. If diagnosis is delayed, percutaneous nephrostomy drainage may be necessary, as conditions may preclude the successful placement of a retrograde catheter.
of a stent. Drainage of any accumulated urinoma or abscess can also be achieved percutaneously. Ligation of the ureter or crush injury from a hemostat, when recognized immediately, can also be treated by ureteral catheterization or stenting if the tissue does not appear severely traumatized.

The principles of management of the injured ureter are similar for iatrogenic and external trauma: clear exposure, debridement of questionable tissue, tension-free and watertight anastomoses using absorbable suture, stenting, and external drainage. The bladder can be mobilized upward to some extent, and the kidney can be mobilized downward to help bridge gaps created by severe injuries.

In the upper and middle segments of the ureter, if the injured segment is short, ureteroureterostomy can usually be achieved (Figure 6). In the lower ureter, direct reimplantation into the bladder is preferable to ureteroureterostomy. If reimplantation is difficult because of a long missing segment of the ureter, a psoas hitch (Figure 7) or a Boari flap (Figure 8) can be done. A transureteroureterostomy is another option if reimplantation, a hitch, or a flap is not possible.

Construction of a neoureter with a segment of ileum is also feasible when the entire ureter has been injured; however, the neoureter may become elongated and tortuous over time, leading to obstruction (Figure 9). In extreme cases where a very long segment or the entire ureter has been injured, autotransplantation can be considered.

Upon surgical reconstruction of the ureter, a ureteral stent, retroperitoneal drain, and bladder catheter are typically left indwelling. The drain may be discontinued when drainage output is reduced, usually no longer than 48 hours. The bladder catheter may be removed in 2 to 7 days and the ureteral stent in 4 to 6 weeks. Late complications following ureteral injury and reconstruction include obstruction secondary to stricture, urinary leak with urinoma and/or abscess formation, fistula, and poor function of the involved kidney. The late complication rate for repaired external ureteral injuries is approximately 20%.

Case 2 Resolution

A retrograde pyelogram is performed and confirms extravasation from the lower left ureter, although some
contrast also passed from that point up to the kidney. A diagnosis of partial tear of the ureter is made, and a stent is placed and left indwelling for 4 weeks. The patient does well clinically, the urinoma is reabsorbed, and the stent is removed 6 weeks later. Six months later, an IVP (Figure 10) reveals good function bilaterally with mild left hydroureteronephrosis.

**Case 3 Resolution**

An attempt to place a ureteral stent in a retrograde fashion is unsuccessful due to ureteral obstruction, and a percutaneous nephrostomy tube is placed in the right kidney. An antegrade pyelogram demonstrates that the injury is in the distal ureter, and the patient undergoes successful reimplantation of the ureter approximately 4 months after the suspected time of injury. Plain radiography of the abdomen, performed at the time of percutaneous nephrostomy tube removal, demonstrates appropriate drainage of her right kidney (Figure 11). The patient’s serum creatinine level returns to normal.
**PREVENTION OF IATROGENIC URETERAL INJURY**

Prevention of injury to the ureter during surgery is best achieved by awareness of ureteral anatomy and by dissection of the ureter with adequate exposure to illustrate its path. Minimal mobilization of the ureter is ideal, and the peritoneum overlying the ureter should be left intact as much as possible. The adventitia should not be stripped, and ureteral arteries should be sought and preserved when ligating the internal iliac or uterine artery. Mass ligation of bleeding tissue should be avoided, relying instead on careful dissection to find and tie or clip bleeding vessels. Not uncommonly, the gonadal vessels may be mistaken for the ureter, which may lead to improper surgical handling of the misidentified ureter.

Preoperative IVP or the placement of preoperative ureteral catheters have not been shown to decrease the incidence of ureteral injury, but stents may help with immediate diagnosis and allow immediate repair. Findings from a 5-year review found that ureteral stents placed prophylactically before colon surgery did not prevent ureteral injuries. If injury is thought to have occurred intraoperatively, intravenous administration of 1 vial of methylene blue will assist in diagnosis, either by noting extravasation of blue dye from the injured ureter or by the absence of blue dye emanating from the involved orifice on cystoscopy.

**PEDIATRIC URETERAL INJURIES**

Pediatric ureteral injuries generally occur from blunt trauma to the abdomen, most often as a result of a motor vehicle accident. The pattern of pediatric ureteral injuries typically mirrors that of adults with the exception that adults sustain more ureteral injuries secondary to penetrating injuries. Ureteral damage in a pediatric patient usually occurs as a result of vigorous trunk hyperextension. Pediatric ureteral injuries are typically diagnosed and treated in a similar manner as adult ureteral injuries. Anatomic location of the ureteral injury dictates the type of management required. As in adults, a ureteral stent left indwelling after surgical repair may lessen the incidence of future ureteral stricture. In a study of 40 ureteral injuries that included 4 children, 3 sustained injury to the ureteropelvic junction, 1 had a vesicoureteral injury, and all injuries occurred as a result of motor vehicle accidents. One patient developed a...
Ureteral injury is relatively unusual. A high index of suspicion is necessary to detect ureteral injury, and early diagnosis and treatment is preferable to delayed diagnosis. Trauma teams in major institutions should include an urologist member to assist in the evaluation and management of any genitourinary injury, including injury to the ureter.

REFERENCES

11. Elliott SP, McAninch JW. Ureteral injuries from external


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