Anatomy

The ureters originate from the renal pelvis and are located dorsal to the renal artery and veins. The proximal normal ureter and renal pelvis can be challenging to expose surgically because they are covered by renal parenchyma. To improve visualization of the renal pelvis and proximal ureter, the kidney frequently needs to be liberated from its peritoneal attachments and reflected toward the opposite side of the abdominal cavity. The ureters are relatively fixed to the dorsal body wall and lie within the retroperitoneal space. The right ureter lies just lateral to the caudal vena cava and in some cases, courses dorsal to the vena cava (circumcaval) before resuming its normal course and then entering into the trigone region of the urinary bladder. One of the challenges in performing ureteral surgery is the sheer size of the internal diameter of the ureter, particularly in cats in which the internal diameter of the ureter is approximately 0.3-0.4 mm. In a CT study of dogs weighing between 21 and 30 kg, the diameter averaged between 2.0 to 2.5 mm. The blood supply to the ureter originates from the renal artery and vein proximally and from the ureteric branch of the caudal vesicular artery and vein distally which in turn arises from the vaginal or prostatic arteries and veins. The blood supply can be visualized running along the adventitial surface. The proximal and distal blood supply anastomose along the length of the ureter.

Obstruction is the most common indication for ureteral surgery in both human and veterinary patients and that obstruction may be congenital or acquired, benign or malignant. Although urolithiasis is most common, other causes of obstruction encountered in our patients include congenital narrowing, trauma including iatrogenic ureteral ligation, fibrosis, stricture, neoplasia and dried solidified blood calculi. The impact of any obstruction on renal hemodynamic variables and GFR is influenced by its chronicity, degree of obstruction (unilateral or bilateral, partial or complete), the baseline condition of the kidneys, and whether or not the obstruction persists or has been relieved.

Urolithiasis in dogs and cats

Ureteral surgery in both dogs and cats can be challenging, even for the most experienced surgeon. What creates this challenge is the sheer size of the ureter, particularly in cats. Meticulous surgical technique in conjunction with appropriate magnification is essential in preventing both short and long term complications. The most common indication for ureteral surgery in our veterinary patients is ureteral obstruction secondary to urolithiasis. Recommendations for treatment often depend on the presentation of a patient which can vary with regard to the number of ureteroliths, the presence or absence of concurrent nephrolithiasis, presence of infection, whether the disease is unilateral or bilateral, the degree of obstruction present, and any underlying kidney dysfunction. Additionally, the duration of obstruction likely impacts the recovery of renal function, however unfortunately in most cases, particularly in patients with unilateral disease, this information is not known.
Calcium oxalate (CaOx) is the predominant stone type identified in the ureter of both dogs and cats. These stones form in the renal pelvis and may subsequently migrate into the ureter. Often in cats, a small, marginally functional, nonobstructed kidney is identified in conjunction with an enlarged, hydronephrotic obstructed contralateral kidney (often referred to as Big Kidney Little Kidney (BKLK) syndrome) and most cases that have a ureteral obstruction due to stones also have underlying chronic renal disease as a secondary issue. In a report by Kyles et al evaluating the clinical, clinicopathologic, radiographic, and ultrasonographic abnormalities in cats with ureteral calculi, 76% (58/76) of cats that had a unilateral ureteral obstruction were azotemic and 55% (39/70) of cats had a small contralateral kidney. In a second report by Kyles et al, looking at the diagnosis and surgical management of obstructive ureteral calculi in cats, in 2 of 3 cats that had GFR evaluated, the obstructed kidney contributed >75% to the GFR.

**Diagnostic evaluation**

At the University of Pennsylvania, clinical presentation, as well as results of imaging studies, help guide the clinician on the best approach for a given patient. Cats with uroliths affecting the ureter can present asymptomatic or with non-specific clinical signs including lethargy, weight loss, anorexia, vomiting, fever, polydipsia, and polyuria. Other signs of uremia including oral ulcerations may be observed. Hematuria may or may not be present. Patients may also present with abdominal pain and splinting or renomegaly. Dogs more commonly present with signs of dysuria including stranguria, hematuria, polyuria, pollakiuria, incontinence, and signs of systemic illness often associated with a pyelonephritis. A complete physical examination, urinalysis/culture, complete blood count and biochemical profile are performed, as many affected patients are older and may have concurrent disease(s). Imaging including survey radiography and ultrasonography are performed on all patients at the time of presentation. Plain abdominal radiography can be helpful with surgical planning by providing information on the number and location of radiopaque renal and/or ureteral calculi. Abdominal radiography has been shown to have 100% specificity, but only a 66% sensitivity in cats for identifying ureteroliths. It is important to note that very small ureteroliths, radiolucent ureteroliths or those overlying colonic contents are occasionally missed. Ultrasonography is often performed in conjunction with plain radiography and provides information regarding the degree of hydronephrosis and or hydroureter secondary to urolithiasis, assessment of the renal parenchyma, and for any evidence of peri-renal inflammation or effusion. Ultrasonography has been shown to have a 100% sensitivity, but only a 33% specificity. Renal pelvic dilation can be identified with other non-obstructive condition, such as pyelonephritis. If no recognizable cortical tissue is present, surgical correction of the ureteral obstruction will likely be of no value to the patient. In one feline report, a combination of survey radiography and abdominal ultrasonography revealed ureteroliths in 90% of patients. Other techniques that may be employed to help identify small ureteroliths as well as delineate the level of the obstruction include compression radiography, intravenous urography, antegrade pyelography, computed tomography angiography, and magnetic resonance imaging. It is important to note that ureteral dilation identified using one of these modalities, does not always extend to the level of the obstruction. Additionally, in patients with subacute obstructions, pelvic and ureteral dilation may not have yet developed.
Medical management

Unfortunately, in cases of CaOx uroliths, medical dissolution is not possible. Therefore, surgical intervention is often recommended if the stones are causing clinical disease. If intervention is necessary, it is not always clear how long one should wait to address ureteral uroliths. If patients are clinically stable, an initial period of medical management may be attempted, including the parenteral administration of fluids alone or in combination with diuretic therapy (mannitol) to determine if passage of ureteral calculi will occur. Additional therapies with anecdotal efficacy include the administration of various smooth muscle relaxants including prazosin, the tricyclic antidepressant amitryptilline and other alpha antagonists such as tamsulosin. Because of the high incidence of urinary tract infections in dogs presenting for ureteral obstructions (>75%), broad spectrum antimicrobial therapy is indicated. In the author’s experience, if medical management does not appear to be effective within 24-48 hours and a partial or complete ureteral obstruction is present, or the ureterolith is associated with an infection that doesn’t respond to medical therapy, surgical intervention is recommended. Additionally, in patients that are unstable, immediate surgical intervention or hemodialysis may be recommended.

Preoperative preparation

Patient stabilization prior to anesthesia and surgery is essential for survival. Dehydration should be addressed with fluid therapy, however fluid overload is a significant concern in these patients and regular evaluation of body weight, urine output and PCV/TP should be performed. All patients should have an ECG placed and if arrhythmias are present and associated with hyperkalemia they should be treated accordingly. Regarding antibiotic treatment, the true incidence of concurrent pyelonephritis in patients with a ureteral obstruction is unclear, but tend to be a more common complication in dogs. In the critically ill uremic patient, if the uremia is associated with infection, aggressive treatment is recommended and should not be delayed until culture samples are collected. Correction of anemia with packed red cell transfusions or type-specific whole blood that are cross-matched compatible should be considered if the PCV is less than 20% or the patient has developed clinical signs associated with the anemia.

Surgical treatment

At the University of Pennsylvania, a decision to perform a traditional surgical procedure, stent or SUB is made based on clinical presentation, imaging studies as well as findings at the time of surgery. In some cases, a combination of techniques may be warranted. Regardless of technique chosen, an important consideration for the surgeon is the availability of equipment as well as long-term equipment costs. Ureteral surgery in cats and small dogs generally requires substantial magnification. In cats and small dogs, the author recommends 8 to 10 times magnification provided by an operating microscope. In larger dogs, surgical loupes providing 2.5x-4.5x magnification may be adequate.

Ureterotomy and double-pigtail stent placement

At our facility, one or 2 stones present in the proximal ureter are often removed by a ureterotomy or less commonly, a pyelotomy. Stones may be visible on inspection of the ureter or palpable
along its length. Once the location of the stones are identified, the affected segment of ureter is isolated using silastic material proximally and distally. In addition to decreasing urine flow into the surgical field, this preparation prevents spontaneous retrograde movement of ureteroliths. Care is taken when manipulating the ureter so as not to disrupt the blood supply or inadvertently traumatize the ureter. A longitudinal incision is made in the dilated ureter just proximal to the obstruction. Occasionally, depending on the location of the stones, removal of multiple stones (>2) from the same ureterotomy incision may be possible. In some cases, because the stone is embedded within the ureteral wall, the incision is made directly over the stone. If ureteral integrity is questioned following removal, a ureteral stent can be placed temporarily to divert urine during the healing process. The author also recommends stent placement in patients following a ureterotomy when the obstructive stone has been associated with a nephropyosis. In addition to diverting urine, the stent allows for continued drainage of purulent material. In this situation, the stent should be removed once the ureterotomy is healed. If a stent is placed in conjunction with a ureterotomy, the ureterotomy incision is closed after the stent is in place. Ureteral stenting has also been used at the author’s facility for patients with multiple ureteroliths located unilaterally or bilaterally with or without the presence of nephroliths. Additionally, stents have also been used successfully for treatment of malignant ureteral obstructions in dogs. Stents can be placed via an antegrade or retrograde approach.

**Ureteroneocystostomy**

Uroliths lodged in the mid to distal ureter may be removed by ureterotomy or the affected area of the ureter may be removed en toto and a ureteroneocystostomy performed. Both intravesicular and extravesicular techniques have been described and used successfully in patients with urolithiasis as well as cases of congenital narrowing, ectopia, trauma, stricture and neoplasia. Although the literature recommends a ureterotomy for stones lodged in the proximal third of the ureter, it is important to note that a ureteroneocystostomy can be performed when only the proximal third of the ureter is available for anastomosis. If tension on the ureteroneocystostomy is expected, renal descensus as well as a cystopexy to the abdominal wall and/or cystonephropexy can be performed. With this technique, the kidney is mobilized from its retroperitoneal attachments and moved caudally. The renal capsule is then sutured to an incision made in the adjacent body wall using 4-6 interrupted sutures of 4-0 polypropylene. The bladder can be fixed cranially to the body wall or to the tendon of the psoas muscle. The nephrocystopexy is performed using 3-0 to 4-0 absorbable or nonabsorbable sutures. Recently, a modification of a Boari flap was used successfully for the treatment of ureteral trauma in one cat and for a proximal ureteral obstruction in a second cat.

The most common complications associated with ureterotomy are leakage and stricture formation. In 2005, a large multicenter study published evaluating 153 cats, found the incidence of urine leakage to be 16%, followed by persistence of ureteral obstruction (6%). In a second study published in 2011 evaluating postoperative mortality in 47 cats after ureterolithotomy, 3 patients (6%) developed a uroabdomen following the procedure. Perioperative mortality was reported at 21% however, based on necropsy findings, the cause of death in approximately half of the cats was associated with progression of their chronic renal disease and not related to complications associated with the surgical procedure. In 4 recent studies (published between 2012-2014) evaluating ureteral stenting in cats, the most common procedural related
complications included uroabdomen (8.7, 15%) and guide wire penetration (17%), and the most common short and long term complications included signs of sterile cystitis (11-35%), urinary tract infection (8-31%), encrustation (11-25%), hematuria (18%) and stent migration (6-11%). Perioperative mortality ranged from 7.5-15% and stent exchange was necessary in 15-27% of cats. In a recent study completed at our facility looking at perioperative complications, mortality and long term outcome of ureteral surgery in 117 cats which included both cases of ureterotomy, stent placement as well as the combination of both techniques, 8 patients (6.8%) developed a uroabdomen (6/8 resolved with conservative therapy) and stricture formation was not identified. Of 87 cats that were available for long-term follow-up, chronic lower urinary tract signs were identified in 17 cats (20%), and a urinary tract infection was identified in 12 cats (14%). These long-term complications were seen most frequently in cats that had a ureteral stent placed with or without a ureterotomy. Stent encrustation was identified in 3 cats (3%). The post-operative mortality rate was 8.5% with the majority of cases euthanized due to progression of their renal disease.

In patients that have concurrent nephrolithiasis and ureterolithiasis, the nephroliths do have the potential to pass into a ureter that was recently unobstructed, but the exact occurrence of this complication is unknown. In the report evaluating the management and outcome of 153 cats with ureteral calculi, a second episode of ureterolithiasis was documented in 14 of 35 cats (40%) in which 12 of the 14 cats had nephrolithiasis diagnosed at the time of the initial examination. Recurrence developed a median of 12.5mo following ureterolithotomy suggesting migration of calculi following the relief of the obstruction. In the study evaluating 117 cats, the incidence of reobstruction was 22%. Of the 117 cats, 38 cats had nephrolithiasis present on the initial ultrasound examination and reobstruction was diagnosed a median of 203 days following the original procedure. Because the majority of stent cases are performed with an open surgical procedure, knowing the incidence of re-obstruction in cases with nephroliths and only a few ureteroliths would be important when making a decision regarding the appropriate treatment option. Patients that have had a ureterotomy performed should be evaluated periodically following surgery for this complication. Because a ureteroneocystotomy can be performed with only a very short proximal segment of ureter, this technique is an option for patients with multiple ureteroliths. Nephrolithiasis has also been successfully addressed in cats using nephroscopy through the renal cortex.

Ureteral anastomosis

Ureteral anastomosis has been used most commonly at our facility for cases of trauma secondary to accidental ligation/transection, however can be considered for cases of stricture or neoplasia. The proximal and distal portions of the ureter are prepared for anastomosis. The vasculature and associated periureteral cuff of fat should be preserved as much as possible and if necessary, the ends of the ureter can be spatulated. To prevent stricture and leakage, an appropriately-sized ureteral stent may be preplaced just prior to the ureteral anastomosis. When a stent is placed, the anastomosis can be performed without spatulation of the two ends. Placement of a stent prevents the incorporation of the back wall of the ureter in the suture line.
Conclusion

Ureteral obstruction in dogs and cats can occur for a variety of reasons and is a common indication for surgical intervention. Multiple surgical treatment options exist for the veterinarian and recommendations may vary depending on the underlying cause and location of the obstruction. Because of the small size of the ureteral lumen, particularly in cats, the use of magnification is extremely important in preventing both short and long term complications. The development of novel reconstructive techniques to treat some of the more complex cases continues to evolve, providing additional options for treatment success.