Ureteral obstructions in dogs and cats: a review of traditional and new interventional diagnostic and therapeutic options

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Abstract

Objective – To describe and review both traditional and newer diagnostic and therapeutic options for canine and feline ureteral obstructions currently being performed clinically in veterinary medicine.

Data Sources – A Medline search with no date restrictions was used for this review.

Human Data Synthesis – The human literature would support the use of minimally invasive endourological techniques for the treatment of nearly all causes of ureteral obstructions, whenever possible. This typically includes extracorporeal shockwave lithotripsy, intracorporeal lithotripsy via retrograde ureteroscopy or antegrade percutaneous nephroureterolithotomy, ureteral stenting, percutaneous nephrostomy tube placement, and laparoscopic endopyelotomy. Typically open surgery is only suggested in cases of ureteral or gynecological malignancy when en bloc resection is considered a good option, or when various methods of endourological techniques have failed.

Veterinary Data Synthesis – The veterinary literature is scarce on the use of interventionale n d o u r o l o g i c a l techniques for the treatment of ureteral obstructions and has been growing over the last 5 years. The current literature reports the use of extracorporeal shockwave lithotripsy for ureteral stones, as well as the use of ureteral stents for the treatment of tririnal obstructive transitional cell carcinoma, ureterolithiasis, and ureteral strictures. Traditional surgical interventions, like ureterotomy, ureteronephrectomy, and ureteral reimplantation is more vastly reported and accepted. This review will focus on new clinical data using interventional endourological techniques for ureteral obstructions.

Conclusions – Various treatment options for ureteral obstructions are now available for veterinary patients, and the trend away from traditional surgical techniques will hopefully be followed now that they are technically and clinically available for dogs and cats.


Keywords: interventional endoscopy, interventional radiology, lithotripsy, nephrostomy tubes, ureteral stents, ureteral stricture

Introduction

Ureteral obstructions can be difficult to diagnose and treat in veterinary medicine. The increasing incidence of ureteral obstructions in veterinary practices, combined with the invasiveness and morbidity associated with traditional surgical techniques, makes the use of newer interventional options appealing. Interventional radiologic (IR) and interventional endoscopic (IE) techniques have enabled clinicians to simultaneously diagnose and treat ureteral disease in an expedited and minimally invasive manner. The technology involved in these techniques includes the use of fluoroscopy, often with flexible and rigid endoscopy, for ureteral visualization and to access various parts of the body. This review will focus on the application of both IR and IE as tools to diagnose and manage ureteral obstructions and aid in an algorithmic approach to these types of cases. It is important to understand that most of the data pertaining to IR/IE treatment of ureteral obstructions are new and still considered investigational in nature. A large proportion of this review article is based on the author’s experience, opinions, and data which have only been published and presented in abstract form. Traditional therapeutic options will be reviewed in addition to new alternatives in dealing with these challenging cases.
Equipment
Various flexible and rigid endoscopes are needed for the following endourologic ureteral procedures. Rigid cystoscopy is used for female (dog or cat) ureteral intervention. Ureteral access is possible in a retrograde fashion in most female patients via IR techniques. Rigid endoscope diameters range from 1.9 to 7.5 mm. Flexible ureteroscopes (7.5–8.2-Fr) are used for cystoscopic access in male dogs and ureteroscopy in both male and female dogs, when possible. Different types of intracorporeal lithotrites and lasers are available including: holmium:YAG, diode, ultrasonic, pneumatic, and electrolydraulic. These are typically used for stone disease or tumor ablation when treating ureteral obstructions. In addition, extracorporeal shock wave lithotripsy (ESWL) has great application for ureteroliths in dogs and sometimes, but less commonly, cats.⁴⁻⁵

A traditional fluoroscopic C-arm is sufficient for visualization and ureteral intervention. A mobile C-arm has the ability to move the image intensifier and gain various tangential views of the renal pelvis and ureter. Ultrasoundography is useful for percutaneous renal access in order to cannulate the ureter in an antegrade manner, or for the placement of a nephrostomy tube. This can also be done under direct fluoroscopic guidance when the renal pelvis is already opacified with contrast. Various guide wires and catheters are also needed for each procedure, and a discussion of these can be found elsewhere.⁴ Ureteral stents, which are available in numerous dimensions, are soft polyurethane-type catheters that have a double pigtail multifenestrated design. They can be easily removed after resolution of ureteral disease if necessary, but are often considered long-term treatment options. Additional interventional techniques that will be discussed for the management of ureteral disease include the placement of nephrostomy tubes and the use of a subcutaneous ureteral bypass (SUB).

Etiology
Ureterolithiasis is the most common cause of ureteral obstructions in both dogs and cats,⁵,⁶ though trigonal neoplasia,⁷ ureteral strictures (congenital or acquired),⁸ dried solidified blood clots/calculi⁹ or other tumor types have also been reported.⁹ Greater than 98% of feline, and over 50% of canine ureteroliths were recently documented to be composed of calcium oxalate.⁵,⁶,¹⁰⁻¹² These types of stones do not dissolve medially and either need to pass spontaneously, be removed, or managed, to permit urine passage. Once medical management fails (traditionally this involves, eg, IV fluid therapy, mannitol continuous rate infusions [CRI], and α-adrenergic blockade, amitriptyline, glucagon), partial obstructions were traditionally tolerated and often left untreated (benign neglect) due to the risk/benefit ratio of attempted surgical removal. If there is a complete ureteral obstruction, decompression of the renal pelvis was typically encouraged. This approach to management has more recently changed in the author’s practice and immediate treatment of partial ureteral obstructions is typically recommended.

The physiologic response to a ureteral obstruction is very complex both before and following its relief. Following a ureteral obstruction studies in normal dogs have demonstrated that ureteral pressures increase immediately and can take over 24 hours after obstruction relief for the pressure to decrease.¹³ After this increase in pressure renal blood flow diminishes to 40% of normal over the first 24 hours and drops to 20% of normal by 2 weeks.¹⁴,¹⁵ The excessive pressure is transmitted to the entire nephron and a decrease in glomerular filtration rate (GFR) occurs via concurrent vasoactive mediator release, leukocyte influx, and subsequent fibrosis.¹⁴ The contralateral kidney will have an increase in the GFR in response. The longer the ureter remains obstructed, the more damage occurs, which may be irreversible depending on severity and duration of the obstruction. In a study of normal dogs, it was found that after 7 days of obstruction the GFR was permanently diminished by 35%, and when the obstruction lasted for 14 days the GFR was diminished by 54%.¹³⁻¹⁸ These numbers were obtained in a canine model with complete obstruction, without pre-existing azotemia, chronic interstitial nephritis, or chronic obstructions, so extrapolation of a worse outcome might be expected in dogs and cats that are obstructed, making aggressive and timely intervention imperative. It was also documented in these studies that it took over 4 months to get the maximal return to function.¹⁶⁻¹⁸ Interestingly, in contrast to the irreversibility of a complete obstruction, partial obstructions resulted in less severe destruction with greater return of function after the obstruction is relieved. In 1 dog model it was found that the GFR returned to normal after a partial obstruction was present for 4 weeks.¹³ Knowing that many patients are partially obstructed with concurrent renal compromise, eg, chronic renal disease (CKD), aggressive management and resolution is recommended to improve overall outcome.

The normal diameter of the canine ureter based on computed tomography (CT) measurements ranges from 1.3 to 2.7 mm (3.9–8.1-Fr).¹⁹ The normal internal diameter of the feline ureter is approximately 0.4 mm (1.2-Fr), whereas the outside diameter reaches 1 mm (3-Fr).²⁰⁻²⁴ The ureter sits in the retroperitoneal space connecting the renal pelvis to the urinary bladder. It is lined with transitional cell epithelium and composed of several layers of smooth muscle surrounding the mucosal layer, allowing the peristalsis of the ureter and urine propulsion from the kidney to the urinary bladder.²⁰,²¹ In the dog and cat the ureteropelvic junction is covered by renal parenchyma. Once the ureter exits the kidney it
passes dorsally. The right ureter typically passes lateral to the caudal vena cava, whereas the left ureter is usually lateral to the aorta. In the case where the ureter is seen to pass dorsal to the caudal vena cava, this is termed a circumcaval (or retrocaval) ureter. In a normal cat, as the ureter passes caudally, it passes ventrally, enters the lateral ligament of the bladder and then the distal end curves resulting in a ‘J-shaped’ hook, entering the dorsal aspect of the bladder neck at the ureterovesicular junction (UVJ). In cats the UVJ is typically found in the proximal urethra at the junction of the trigone.

Ureteral interventions in people

In human urology the development and improvements in ureteroscopy, ureteral stenting, ESWL, laser lithotripsy, laparoscopy, and percutaneous nephroureterolithotomy (PCNUL) have almost eradicated the need for open ureteral surgery for stone disease, strictures, trauma, neoplasia, and congenital anomalies. Currently, ureteroscopy is the first line modality for the evaluation and treatment of ureteral neoplasia, upper tract essential hematuria, ureteral calculi >5 mm, and evaluation for ureteral obstructions. Ureteroliths <5 mm have a 98% chance of spontaneous passage with medical management alone (eg, α-blockade).

For larger stones, or those that do not pass spontaneously, ESWL is effective in 50–81% of cases, though most of the literature suggests this number is closer to 50–67%. Ureteroscopy has a near 100% success rate when a holmium:YAG laser lithotripsy is used. PCNUL has been successful for large proximal impacted ureteral stones. Ureteral stenting was first introduced in 1967 for management of people with malignant ureteral obstructions. They are still widely used to treat both benign and malignant obstructive disease and this is considered standard-of-care in many instances. There has been documented success in stent placement for distal malignant obstructions of >96% when placed in an antegrade manner when nephrostomy access is obtained through the kidney, versus only 50% when placed in a retrograde manner. Ureteral stenting for stone disease is typically done after ureteroscopy for the management of postscoping spasm and edema, and in children it has been performed before ureteroscopy to allow for passive ureteral dilation, immediate ureteral bypass, future ureteroscopy, and spontaneous stone passage. With this understanding a similar approach is starting to be used in veterinary medicine over the past 5 years in a few veterinary facilities.

History and clinical presentation

Feline patients with ureteral obstruction(s) typically present with vague signs associated with vomiting, lethargy, a decreased appetite, and acute or chronic weight loss. If the patient is severely azotemic then signs of uremia may be present such as polyuria, polydipsia, vomiting, anorexia, oral ulcerations, weakness. Unless there are concurrent bladder or urethral stones, or a trigonal mass, signs of dysuria are not commonly observed. Concurrent urinary tract infections are not as common in cats (approx 33%) as in dogs (77%), and ureteral colic can be associated with signs of dysuria or stranguria, but this appears to be less common in cats than dogs. Pain on palpation of the affected kidney is more commonly seen in acute obstructions.

Clinical presentation in dogs with a ureteral obstruction is typically associated with dysuria (incontinence, stranguria, hematuria, polyuria, pollakiuria) and signs of systemic illness (eg, vomiting, inappetence, depression, lethargy). Most dogs (77%) with a ureteral obstruction have associated pyelonephritis and cystitis. This is perhaps why more dogs have generalized signs of systemic illness. Dramatic signs of lower urinary tract disease are more commonly associated with ureteral colic, cystitis, or concurrent lower urinary tract disease (eg, trigonal tumor, urethral or bladder stones, polyps, masses).

Diagnosis

On physical examination it is common to palpate 1 enlarged kidney and 1 small kidney in cats. In dogs renal pain is more common and is typically associated with the concurrent pyelonephritis and capsular inflammation. Pallor and associated anemia is common in cats, and evidence of a heart murmur is often auscultated.

Biochemical parameters: Cats are often anemic (48%) at diagnosis and this is either due to concurrent CKD or from excessive blood sampling during previous hospitalizations. Dogs often have a moderate to severe neutrophilia associated with concurrent pyelonephritis and 44% of dogs with ureterolithiasis-induced obstructions were reported to have some degree of thrombocytopenia, which can be quite severe (<40,000 platelets). The thrombocytopenia may be secondary to sepsis or a secondary immune-mediated thrombocytopenia. Azotemia is common at the time of diagnosis (83% of cats and 50% of dogs were azotemic with a unilateral obstruction). The degree of azotemia does not appear to be associated with outcome if early decompression is undertaken. Hyperphosphatemia was documented in 54%, hyperkalemia in 35%, hypercalcaemia in 14%, and hypocalcaemia in 22% of cats with ureteral obstructions. On urinalysis crystals were observed in the urine of 29% of cats (amorphous crystals and calcium oxalate being most common). Urinary tract infections were documented in 8% of cats in 1 study and over 30% of cats in another study, whereas 77% of dogs were documented to have positive stone or urine bacterial cultures.

Imaging: Bilateral ureteral obstructions were documented in 19% of cats and 12.5% of dogs.
Radiopaque calculi (Figure 1) are typically visible in patients with calculi-induced obstructions. In some patients an enema is necessary in order to better visualize the entire ureter and associated renal pelvis. The combination of radiographs and ultrasound is preferred in the diagnosis of ureteral obstructions. The benefit of the radiographs is to document stone size, number, location, and the presence of concurrent nephrolithiasis. These are often underestimated with ultrasound. Ultrasound is ideal for the documentation of hydronephrosis, and the exact location of the obstructive lesion. If a trigonal tumor is presently causing the ureteral obstruction then a hydroureter would be expected to extend to the level of the UVJ. If hydronephrosis is present and very proximal, with no evidence of a shadowing stone at the junction of normal and abnormal ureter, then one might expect a ureteral stricture to be present. In a recent study 60% of cats with a ureteral stricture had evidence of peri-ureteral hyper-echoic tissue at the stricture site on ultrasound.\textsuperscript{b} Identifying concurrent nephroliths and other ureteroliths is vital in therapeutic decision making when considering traditional surgery, ureteral stenting, or ESWL. One study documented 62% of cats had concurrent nephroliths and 9% cystic calculi, whereas 50% of canine patients had concurrent nephroliths.\textsuperscript{5,6,12} Another key piece of information is knowing the exact diameter of the dilated renal pelvis based on the ultrasound. It is important to know which interventional option is best for each patient and ensure that the loop of a locking-loop pigtail nephrostomy tube or ureteral stent fits inside the renal pelvis if that modality is being considered. The sensitivity for abdominal radiographs for feline ureteral calculi was 81% (versus 88% in dogs) and for abdominal ultrasound was 77% (versus 100% in dogs).\textsuperscript{12} In combination the sensitivity of both radiography and ultrasound was 90% in cats.\textsuperscript{5,6}

**Percutaneous antegrade pyelography:** Percutaneous antegrade pyelography provides good visualization of the renal pelvis and ureter, and allows localization of the ureteral obstruction and aids in determining whether a complete or partial obstruction is present.\textsuperscript{36} In brief, the animal is anesthetized, or heavily sedated, and the area over the kidney is clipped and aseptically prepared. Using ultrasound guidance and a 22-G IV catheter the renal pelvis is approached through the greater curvature of the kidney. The needle is attached to a 3-way stopcock and extension set. Once inside the renal pelvis, urine is collected for bacterial culture and urinalysis and iohexola is injected (comprising 50% of the urine volume that was removed). Images should be obtained immediately and again at 5 and 15 minutes. Ideally, this procedure should be performed under fluoroscopic guidance, which allows visualization of the filling of the ureter and the point of obstruction in real time. In a study of 11 cats the sensitivity and specificity was excellent in the cases where the study could be interpreted.\textsuperscript{36} Forty-four percent of the studies had evidence of leakage and 30% was not diagnostic, making its use somewhat more limited.\textsuperscript{36} With the improvement in ultrasound imaging, the confidence of obstruction based on ultrasound and radiographs, the more aggressive treatment of partial obstructions, as well as the need for pyelography during treatment (ureteral stenting, nephrostomy tube placement, or SUB placement), the use of purely diagnostic antegrade pyelography has declined tremendously in the author’s practice, and is instead performed intraoperatively during obstruction relief (Figure 1).

**Retrograde ureteropyelography** is performed via cystoscopy and fluoroscopy by cannulating the UVJ and injecting contrast.\textsuperscript{4} This procedure allows for irrigation of contrast in a retrograde manner in order to document ureteral patency, space occupying lesions, stone disease, tortuosity of the ureter, and the ureteral diameter. This is seemingly more accurate than IV pyelography (IVP), allowing for ureteral distension and higher contrast concentrations during ureteral irrigation without the dilutional effect observed with an IVP and the potential risk of contrast-induced nephropathy. The contrast agent remains in the renal collection system and is not injected intravascularly, having no ill effect on the nephrons. This procedure is also less invasive than antegrade pyelography, eliminating the need for needle access and the risk of subsequent bleeding or urinary leakage through the renal parenchyma if a ureteral obstructive lesion persists (Figure 1).

**CT:** Computed tomography can be performed preoperatively when traditional surgical options are anticipated if the stone number and location is not clear based on radiographs and ultrasound. IV contrast administered during the CT scan can aid in concurrent differentiation of partial or complete obstructions. IVP is often not useful in animals with ureteral obstructions due to the poor filling of an obstructed kidney and the nephrotoxicity risk of the contrast material that is being filtered by the kidneys during the nephrogram phase, particularly considering a significant number of both dogs and cats are azotemic at the time of diagnosis. The risk is theoretical at this point but should be considered. In certain instances an IVP might be indicated. With the advent of ureteral stenting, the location of the stones is slightly less important if the entire ureter will be bypassed by a stent, and most of the stones will not ultimately be removed. This is not the case when traditional surgical therapy is being performed.
GFR studies/scintigraphy: The GFR of individual kidneys can be measured by technetium Tc 99 diethylenetriamine pentacetic acid scintigraphy. The GFR of an obstructed kidney is most often reduced, and the predictability of return to function based on scintigraphy is often unclear, potentially significantly underestimating postrelief renal function. The measurement of the GFR of the contralateral kidney may assist in the decision whether to treat unilateral or bilateral obstructions, or potentially perform a nephrectomy if absolutely necessary (not typically recommended).22

Treatment
There is a paucity of information reported in the literature on the treatment of canine or feline ureteral obstructions aside from a large surgical case series in cats (153 cases)6 and 1 small surgical case series in dogs (16 cases).12 Other reports are often based on anecdotal experience or a subset of patients from this larger case series.

Medical management: Medical management should be initiated immediately following diagnosis of a ureteral obstruction, as stabilization is often required and a majority of cats will present with concurrent kidney disease and azotemia. Medical management alone has been shown to be effective in a minority of cats with stone disease in 1 study,5 and there are no reports in dogs. Only 17% of patients were reported to have movement of their ureteral stones to either complete or partial passage with aggressive medical management.6 It is important to remember that movement to a partial obstruction is not considered resolution of the condition, and progressive renal damage will likely still ensue, albeit at a slower rate. Because there is a small chance of complete stone passage (typically under 10%), medical management should always be considered before any more invasive intervention.6 Dogs may not always present azotemic, but because over 75% of dogs with a ureteral obstruction had concurrent urinary tract infections broad spectrum antimicrobial therapy is indicated.12 It is very important that if medical management is not successful in relieving the obstruction within 48–72 hours, as documented via serial radiographs, blood work, and ultrasound examinations, more aggressive interventions should be considered in order to avoid excessive loss of renal function.

Medical management should consist of aggressive IV fluid therapy, being careful to monitor central venous pressures, body weight, electrolyte concentrations, and hydration status. It is not uncommon for patients, particularly cats, to become fluid overloaded both before and after any ureteral intervention. This is typically seen preoperatively during a diuresis period or postoperatively during high IV fluid therapy rates. Care should be taken to prevent excessive fluid volumes and monitor hydration status very carefully. The fluid therapy protocol typically recommended by the author includes administering a maintenance rate of fluids (eg,
50–60 mL/kg/d) using 0.45% saline mixed with 2.5% dextrose and then a replacement fluid (typically avoiding saline if possible due to sodium load) to correct hydration status and promote diuresis (eg, 45–75 mL/kg/d). Again, careful monitoring of fluid therapy is very important. In addition to IV fluid therapy the use of an osmotic diuretic is often recommended. For patients that do not have any cardiac compromise, a CRI of mannitol is typically chosen by the author. The author starts with a bolus at 0.25–0.5 g/kg over 20–30 minutes followed by a CRI at 1 mg/kg/min for 24 hours. If after 24 hours there is no evidence of improvement based on imaging this is discontinued. Other medical considerations include amitriptyline,\textsuperscript{37} \(\alpha\)-adrenergic antagonists (tamsulosin or prazosin),\textsuperscript{38} or glucagon therapy.\textsuperscript{6} In cats only anecdotal evidence exists regarding the medical management strategies discussed. One study evaluated the response of normal canine ureters and compared various spasmyotics.\textsuperscript{38} In people, \(\alpha\)-1 adrenergic antagonists, eg, tamsulosin (\(\alpha\)-1a/1d adrenergic antagonist), was the treatment of choice for the expulsion of small ureteral stones. It is a very potent spasmyotic and is very effective in relieving a ureteral obstruction when stones are distal and <5 mm in diameter.\textsuperscript{39} A study in dogs comparing various antispasmodics including \(\alpha\)-adrenergic antagonists (tamsulosin, prazosin [\(\alpha\)-1 non-selective–adrenergic antagonist], an experimental \(\beta\)-2/\(\beta\)-3 adrenergic agonist, verapamil [a calcium channel blocker], and papaverine [a phosphodiesterase inhibitor]), showed that the \(\beta\)-adrenergic agonist had the most efficacious ureteral relaxant abilities, and tamsulosin was the second most effective.\textsuperscript{39} Prazosin had little effect, and was actually shown that in high concentrations it enhanced spontaneous contractions.\textsuperscript{38} This suggests that further investigation into the use of a \(\beta\)-adrenergic agonist or tamsulosin in dogs and cats with ureteral obstructions is warranted. Amitriptyline is a potent urinary smooth muscle relaxer mediated by the opening of voltage-gated potassium channels. One study evaluating amitriptyline in cats with urethral obstructions demonstrated that amitriptyline was effective in relieving urethral obstructions and relaxing the muscle of normal human and porcine ureteral segments.\textsuperscript{37} This has since been extrapolated for use in canine and feline ureteral obstructions. The recommended dose is 1 mg/kg, PO, per day but no documented clinical evidence has been reported for its use in veterinary ureteral disease.\textsuperscript{37} Glucagon is another medical option which theoretically causes relaxation of the ureteral smooth muscle, promoting passage of ureteral calculi. An abstract evaluating the use of glucagon for ureteral obstructions in 25 cats\textsuperscript{6} demonstrated that glucagon improved urinary output in previously oliguric cats but there was no documented short- or long-term benefit for the ureteral obstruction.\textsuperscript{6} Major side effects associated with glucagon include vomiting, diarrhea, dyspnea, and tachypnea. The dose of glucagon reportedly used is 0.1 mg/cat, IV, every 12 hours for up to 4 doses; however, many clinicians would recommend against its use, or recommend its use with caution. Another study evaluated glucagon and ritodrine in a canine model of ureteral obstruction.\textsuperscript{40} This study demonstrated a reduction in intraluminal pressure of the ureter and a reduction in the peristalsis rate, but the effect was not particularly prolonged, and was considered clinically irrelevant.\textsuperscript{40}

When medical management fails or the patient is unstable (eg, hyperkalemic, excessively overhydrated, or becoming oliguric) then immediate intervention should be considered. If immediate resolution (via ureterotomy, ureteral reimplantation, ureteral stenting, or SUB) is not possible then the 2 best options are either to place a nephrostomy tube\textsuperscript{d} or initiate intermittent hemodialysis or continuous renal replacement therapy (CRRT). The author typically recommends immediate renal pelvis decompression over hemodialysis or CRRT if the patient is stable to undergo anesthesia and the operator is comfortable placing the draining tube. By relieving the obstruction several goals are accomplished: (1) improvement of azotemia and electrolyte status, (2) prevention of further nephron damage from the increased hydrostatic pressure, (3) alleviation of the ureteral colic caused by the obstruction, (4) enabling the potential for retrograde migration of the obstructing stone after ureteral decompression, and (5) allowing time for a postobstructive diuresis to occur through the nephrostomy catheter (which is a larger diameter) rather than a smaller diameter ureteral stent or edematous ureteral surgical site.

**Nephrostomy tube placement:** A nephrostomy tube (Figure 2) will rapidly and effectively relieve a ureteral obstruction, as well as enable the determination of whether adequate renal function remains before subjecting a patient to a prolonged anesthesia for definitive ureteral surgery. The catheter recommended for this procedure is a locking-loop pigtail catheter.\textsuperscript{5} A study using a dog model for ureteral obstruction demonstrated that after a nephrostomy tube was placed 75% of the dogs passed an implanted artificial steel ball, which was the stone model, into the urinary bladder.\textsuperscript{41} A smooth metal ball should pass much easier than an irregular calculus, but these data may suggest that by relieving the increased ureteral and renal pelvic pressure the excessive ureteral spasm and edema created by the stone may be relieved and encourage stone passage. This is speculative, but possible. In a recent series of 19 dogs and cats, locking-loop nephrostomy tube placement was reported.\textsuperscript{4} No leakage occurred in any of

\textsuperscript{5} Veterinary Emergency and Critical Care Society 2011, doi: 10.1111/j.1476-4431.2011.00628.x
these patients, but 1 dog accidentally removed the tube at home while running out of the crate 5 days after placement. This dog did not have a nephropexy as his tube was placed percutaneously, and no ill effects were noted from this incident.

It is recommended that nephrostomy tubes should be placed percutaneously in dogs and surgically in cats due to the mobility of the feline kidney and greater risk for leakage without a surgical nephropexy. The loop on the catheter is approximately 10 mm in diameter so this procedure is reserved for dogs and cats that have a renal pelvis > 10 mm. If the entire loop is not securely situated inside the renal pelvis then leakage can occur. The author typically use a 6-Fr catheter in dogs and a 5-Fr catheter in cats. Percutaneously, this procedure is performed with ultrasound, fluoroscopic guidance, or

Figure 2: Nephrostomy tube placement. Seldinger-technique displaying the placement of a locking-loop pigtail catheter over a guidewire inside the renal pelvis of a feline patient. (A) A pigtail catheter over a guidewire showing it is straight to start. (B) Once the wire is removed the loop starts to form. (C) Once the string is locked in the loop tightens. (D) Representing the catheter over the guidewire inside the renal pelvis after a pyelogram is performed. (E) The loop of the pigtail is advanced over the wire as depicted in (B). (F) The lock is formed inside the renal pelvis, as depicted in (C). (G) One-stab technique showing the sharp trocar inside the stylette of the locking-loop pigtail catheter. (H) A percutaneous pyelogram in a cat with a proximal ureteral stricture. (I) A locking-loop pigtail catheter being advanced into the renal pelvis with the sharp trocar (white arrow) through the greater curvature of the kidney. (J) The locking-loop pigtail catheter in place and locked inside the renal pelvis.
both. With ultrasound alone a ‘one-stab’ technique can be performed. A stab incision is made through the skin in the location of puncture. The locking-loop pigtail catheter is straightened by the hollow stylette. Then the sharp trocar is placed within the hollow stylette (which come together as a set). This sharp trocar is used to puncture the greater curvature of the kidney with careful ultrasound guidance. Large vessels should be avoided with color-flow Doppler when possible. Once the catheter is seen inside the renal pelvis the sharp trocar is removed. Now the hollow stylette is carefully withdrawn from the catheter as the pigtail catheter is advanced into the renal pelvis. Once the catheter is seen to start forming a curl the locking string is gently pulled tight to encourage the pigtail to form and lock inside the renal pelvis. Once the catheter is in place urine should be removed from the catheter and emptying of the renal pelvis should be documented on ultrasound. At this time a pyelogram can be performed to confirm that no leakage has occurred. The catheter is securely sutured to the skin by purse-string suture followed by finger trap suture pattern. The tube should be tacked to the skin in 3–4 separate locations using surgical tape or serial finger traps to secure the tube from any possible traction to the kidney. The tube should then be wrapped and secured carefully around the abdomen. This should remain in place for 2–4 weeks for tract formation, or the hole can be closed surgically if a laparotomy for definitive resolution is subsequently performed. If the tube is placed surgically, which is recommended in cats, a surgical nephropexy is concurrently performed and the tube can be removed as soon as the ureteral obstruction is permanently relieved.

The ‘Seldinger-technique’ for nephrostomy tube placement requires both ultrasound and fluoroscopic guidance. For this procedure a pyelocentesis and ureteropyelogram is performed using a renal access needle under ultrasound guidance. Under fluoroscopic guidance, an angled guidewire is passed through the needle and coiled into the dilated renal pelvis. The locking-loop pigtail catheter is then straightened out with the hollow trocar. The renal access needle is removed, and the nephrostomy tube set is advanced over the guidewire into the renal pelvis. Once the catheter is observed via fluoroscopy to be inside the renal pelvis, the catheter is advanced off the hollow stiff stylette and the curl is formed over the wire inside the renal pelvis. Once the curl is in the renal pelvis entirely the pigtail is locked and the catheter and hollow stylette are removed. The catheter is secured to the body wall as described above. The tube should be tested with a pyelogram to ensure that no leakage is present or that there is no resistance to drainage. The entire system is then attached to a closed gravity drainage collection system. This allows for external renal drainage, elimination of excessive hydrostatic pressure, and patient stabilization before a more permanent fixation (eg, ureterotomy, ureteral reimplantation, ureteral stent placement, ureteral bypass). During nephrostomy tube placement the guidewire maybe be able to be advanced down the entire ureter around the obstruction. If it bypasses the obstruction, and through and through access is obtained, a ureteral stent can be placed as detailed later in this review.

**Dialysis:** Dialysis, including initiate intermittent hemodialysis and CRRT, may be useful to stabilize patients with ureteral obstruction. In particular, patients with severe hyperkalemia or life-threatening volume overload (ie, pulmonary edema) may benefit from these types of treatment. Dialysis can make the patient more stable for anesthesia for a definitive procedure (eg, ureterotomy or ureteral stent placement). While placing a dual lumen catheter for dialysis may require sedation, it is generally a quick procedure with less morbidity than surgery or percutaneous nephrostomy tube placement. The optimal treatment protocol will depend on the specifics of the case. Because many of these patients suffer from volume overload and marginal hypotension, slow gradual removal of the fluid over several hours (eg, 6–24h) may be desirable. If definitive care is not immediately available, dialysis can be performed daily or continuously until the procedure can be scheduled.

**Surgical management:** Traditional intervention has been accomplished surgically via ureterotomy, ureteral reimplantation, ureteronephrectomy, and at times renal transplantation. Kyles et al. reported 2 retrospective studies involving over 150 cats. There were various procedure-associated complications (over 30%) and the mortality rates ranged from 18% to over 30%, depending on the type of procedure performed or management necessary (eg, concurrent nephrostomy tubes or hemodialysis). These studies not only included cats that had a ureterotomy or ureteral reimplantation, but also those that had renal transplantation or ureteronephrectomy procedures. Considering most cats with a ureteral obstruction are not considered candidates for ureteronephrectomy (with the majority [>80%] being azotemic), and a renal transplantation should be reserved for patients with irreversible renal azotemia, not necessarily postrenal azotemia, the outcome for the type of patients we see clinically is likely different than the larger series reported previously. The studies published by Kyle and colleagues were collaborations from 2 universities with extensive experience in ureteral surgery when compared with most surgical practices or institutions, as active renal transplantation programs existed and microsurgical expertise was available at that time. The morbidity and mortality may be higher in
environments where operating microscopes and microsurgical expertise is not as readily available. These were also cases that were considered ‘surgical candidates,’ where more recently the large number of stones commonly seen in a feline ureter and renal pelvis\(^6\) make surgical intervention alone challenging, if not sometimes impossible (Figure 1).

Depending on the site of obstruction, the number of stones obstructing, and the reason for the obstruction, the type of surgery considered may vary. A ureteronephrectomy would be the least complicated procedure with the least number of procedure-associated complications when compared with other ureteral surgical options. Patients who are nonazotemic and have a normal GFR to the contralateral kidney would be the only candidates for this procedure. Knowing that over 30\% of older cats will develop chronic kidney disease\(^3,44\) with time, and many cats will eventually develop a stone in the contralateral kidney/ureter, removing 1 of the kidneys rather than treating the underlying ureteral disease is less than ideal and cannot be recommended. There is also evidence from the limited literature that over 50\% of cats and nearly 40\% of dogs will remain azotemic after treatment of a ureteral obstruction, further supporting the need to preserve all renal function when possible and avoiding ureteronephrectomy.\(^c,6,12\)

A ureterotomy or ureteral reimplantation are the 2 most commonly performed traditional surgical techniques for the treatment of ureteral obstructions in dogs and cats. It is very important to be sure that all stones are removed during this surgery as stones <1 mm in diameter may be difficult to palpate digitally at the time of surgery and can result in surgical site obstruction. Finally, if the obstruction is very proximal then a nephrocytostomy and ureteral reimplantation or renal descensus and psoas cystopexy may be considered.\(^22\)

Many of the associated complications with surgery are due to site edema, recurrence of a ureteral obstruction from stones that pass from the renal pelvis to the surgery site, stricture formation, and ureterotomy-associated or nephrostomy tube-associated urine leakage.\(^b,5,6\) In the study by Kyles et al\(^5\) over 10\% of cats that survived the these surgical complications required a second surgical procedure during the same visit and 30\% were subsequently euthanized or died for serial complications.\(^5\) Of the large number of cats in that study, a relatively small number had long-term imaging follow-up, and 40\% of those that were followed had evidence of a recurrence of a ureteral obstruction, from either further stone formation or passage of a previous nephrolith. Eighty-five percent of the cats that had stone recurrence had evidence of nephrolithiasis at the time of the first ureteral surgery.\(^6\) The number of animals that did not have stone recurrence with prior nephrolithiasis was not evident in that study. In spite of all of the surgical concerns, the survival rates were dramatically higher for cats that had intervention performed when compared with those treated with medical management alone.

Finding a less invasive alternative that results in immediate decompression and stabilization of associated azotemia, addresses all stones in both the kidney and ureter to prevent future obstructions, preventing reobstruction, stricture or leakage, and concurrently allows patency to be established would be ideal. In people, minimally invasive treatments have largely replaced open surgery.\(^25–35,45,46\) The placement of a double pigtail ureteral stent, either minimally invasively (IR technique) or surgically assisted, could potentially circumvent the complications of surgery alone (eg, leakage, stricture, reobstruction), prevent nephroliths from causing future obstructions, and quickly and efficiently stabilize the patient while decreasing renal pelvic pressure and stopping the cycle of pressure-induced nephron death and renal fibrosis.

**Interventional management**: As already described, nephrostomy tube placement is considered an interventional procedure, requiring fluoroscopy, ultrasound, or both. Ureteral stenting (Figures 3–5) has been performed for a variety of disorders in both dogs and cats.\(^a,\)\(^b,\)\(^c\) This procedure has been performed successfully in over 150 cases in the author’s practice to date. The goals of ureteral stenting are 5-fold: (1) to divert urine from the renal pelvis into the urinary bladder to bypass a ureteral obstruction, (2) to encourage passive ureteral dilation (for ureteral stenosis/strictures, multiple ureteral stones, prevent reobstruction, encourage stone passage, or future ureteroscopy), (3) to decrease surgical tension on the ureter after/during surgery (especially resection and anastomosis) and prevent postoperative leakage and edema, (4) to aid in extracorporeal shockwave lithotripsy for large obstructive ureteroliths or nephroliths that could result in serial ureteral obstructions if the stones do not completely pass down the ureter passively, a term called Steinstrasse,\(^45\) and (5) to prevent the migration of nephroliths resulting in future ureteral obstruction. The main type of ureteral stent used in veterinary medicine is an indwelling double pigtail ureteral stent\(^k\) (Figure 3). The double pigtail stent is completely intracorporeal and can remain in place for numerous months-years if necessary (recommended for <3–6 mo in people but has been left in place for over 4 y in dogs and cats). In many circumstances in the author’s practice this is currently considered a long-term treatment option for various causes of ureteral obstructions in both dogs and cats.\(^a,\)\(^b,\)\(^c,\)\(^7\) It is important to realize that ureteral stenting in dogs and cats should still be considered investigational and that the data below are solely based on the experience of 1 group of investigators.

\(^{94}\)
The first report of ureteral stent placement was in 1967 in a person suffering from a malignant obstruction. Because of the presence of the tumor at the UVJ, access through an antegrade percutaneous approach is typically performed, in order to gain access down the ureter. There are few veterinary studies or clinical cases reported in dogs or cats with ureteral stents.

Stents have been placed successfully as a long-term treatment option in veterinary patients, contrary to our human counterparts. Ureteral stents are most often placed cystoscopically in dogs and, when possible, in female cats. This is done in a retrograde manner through the ureteral orifice at the UVJ using cystoscopic and fluoroscopic guidance. They can also be placed antegrade, through the renal pelvis percutaneously or surgically. Surgical stent placement is most common in cats and this is accomplished via pyelocentesis (antegrade), a cystotomy to access the UVJ (retrograde), or through an ureterotomy (antegrade or retrograde).

The retrograde technique (Figure 4) typically uses cystoscopy concurrently with fluoroscopy. An angled hydrophilic guidewire is advanced into the distal ureter from the UVJ. The wire is advanced up the distal ureter and an open-ended ureteral catheter is advanced over this wire to the distal ureter for a retrograde ureteropyelogram to aid in identifying any lesions, stones, or filling defects in the ureter or renal pelvis. Once the ureterogram is performed the wire is readvanced up the ureter and care is taken to bypass the obstruction and gain access into the renal pelvis. The catheter is then withdrawn and an indwelling double pigtail ureteral stent is placed over the guidewire with 1 curl remaining in the renal pelvis in front of the obstruction and the other curl is pushed into the urinary bladder with the entire shaft sitting in the ureteral lumen.

The antegrade technique (Figure 5) requires percutaneous or surgical pyelocentesis with a renal access needle or over-the needle IV catheter (18-G in dogs; 22-G in cats). This can be performed using ultrasound, fluoroscopy, or via surgical palpation for guidance. The guidewire is passed down the ureter guided by an ureteropyelogram, into the urinary bladder and out the
urethra to have through-and-through access (flossed). This is the typical approach for a trigonal-induced malignant ureteral obstruction when the ureteral orifice cannot be identified cystoscopically, or for small male dogs and male or female cats where cystoscopy for retrograde ureteral access is not possible. The stent is then placed in a retrograde fashion over the wire, as described above, to keep the hole in the kidney as small as possible. These procedures can also be done intraoperatively when surgical success is in question, leakage is a concern, or obstructive neoplasia is found. Indwelling drainage is an ideal, long term, and safe option.

At this time the success rate for ureteral stent placement is ~98% in dogs (n = 84) and ~94% in cats (n = 62). This has improved tremendously since the development of a smaller diameter and different material feline ureteral stent. This can be typically accomplished noninvasively with fluoroscopy and cystoscopy with or without ultrasound in most dogs, and with surgical assistance and fluoroscopy in most cats.

One abstract on ureteral stenting in cats, where the first 47 obstructed feline ureteral units were reported (with various types of stents) approximately 20% of the obstructions were due to ureteral strictures (half due to a previous ureteral surgery and the other half due to a circumcaval ureter), and approximately 80% were due to ureterolithiasis (calcium oxalate or dried solidified blood clots). Approximately 75% of patients had evidence of nephrolithiasis at the time of stent placement, the median number of stones in the obstructed ureter were 6, and approximately 10% were bilaterally obstructed. Over 80% of patients in this population would have required 2 or more ureterotomies to correct the ureteral obstruction, and the majority were considered nonsurgical candidates. Over 90% of the cats were azotemic at presentation (median creatinine ~ 398 µmol/L [~ 4.5 mg/dL]), while approximately 40% remained azotemic after stent placement (median creatinine ~ 220 µmol/L [~ 2.5 mg/dL]).

Complications were separated into 4 categories including procedural (during the ureteral stent placement), peri-operative (within the first week typically during hospitalization), short term (1 wk to 1 mo) and long term (>1 mo). There were relatively few identified procedure related complications. In patients requiring a concurrent ureterotomy, when leakage of urine postoperatively was anticipated, a closed-suction abdominal drain was typically placed. Leakage was rare, and when occurred typically resolved within 24 hours. No patient required a second surgery for leakage once a stent was in place. Peri-operative reobstruction was not seen. The peri-operative mortality rate was under 10%, and the cause of death or euthanasia in this patient population was due to nonurinary causes, eg, congestive heart failure, pancreatitis. No patient was deemed to have died from the

Figure 4: Retrograde ureteral stent placement in a dog. (A) Cystoscopy being performed under fluoroscopic guidance as a guidewire (black arrow) is being advanced up the ureter at the ureterovesicular junction through the working channel of the cystoscope. An open-ended ureteral catheter is advanced over the guidewire (white arrow) for a retrograde ureteropyelogram to aid in stent placement. (B) Guidewire being advanced up the ureter to the level of the renal pelvis (white asterisk). (C) The guidewire (black thin arrow) being coiled inside the renal pelvis (white asterisk) as the ureteral stent (thick black arrows) is being advanced over the guidewire through the cystoscope. (D) The double pigtail stent is pushed into the urinary bladder through the cystoscope so that each loop is indwelling inside the patient.
procedure or as a complication from ureteral disease. Only approximately 5% of cats did not have a significant improvement in the serum creatinine concentration after ureteral decompression with a stent. Those few patients went on to either succumb to renal azotemia or receive a renal transplantation.
There were few short-term (from 2 wk to 1 mo) complications documented including dysuria (in a minority of cats and this was typically self-limiting within 2–14 d of onset). Patients that failed to improve received a short course of glucocorticoids and signs improved in nearly all of them. The long-term (>1 mo postoperative) complications were less serious and included pollakuria (~17%), stent migration (~5%), ureteritis (~3%), tissue in-growth on the stent (~7%), chronic mild hematuria (~10%), ureterovesicular reflux (~1%), and urinary tract infections (~20%). All of these complications were rare but clients should be aware of the risks. Nearly all of these complications were manageable with either medical therapy or a minor outpatient procedure, and none were deemed related to patient mortality.

Stent encrustation is the major complication observed in people but this has not been appreciated in the veterinary patients. Typically, stent mineralization in people is associated with encrustation and is indicated on abdominal radiographs as mineralization of the stent material covering it with stone debris. This makes it become obstructed and extremely difficult to remove. This has not been observed in any of the canine or feline stented patients on routine radiography. Interestingly, the ureters remained patent long term in nearly all cats with the longest stent in place for over 4 years. No patient to date is deemed to have died of ureteral-related disease and to date only 5% of cats died of progressive CKD within the time span of this study (median >380 d; as most are still alive).

The complications observed in dogs were few in all time periods (peri-operative, short- and long term). These included stent migration (<5%), stent occlusion (<5%), urinary tract infections (<10%). Dysuria is much less common in dogs than in cats after stent placement and both species are typically glucocorticoid responsive if necessary.

These preliminary data would suggest that ureteral stenting in both dogs and cats are safe and effective resulting in immediate decompression of the renal collection system. Few major procedural or peri-operative complications occurred, particularly in dogs, but the learning curve was steep. The equipment has dramatically improved over the past 4 years making stent placement less complicated and faster. In cats long-term stent exchange or manipulation may be necessary if a ureteral reaction or stent migration occurs, but this is relatively uncommon. All owners should be prepared for ‘stent upkeep.’ Readers should understand that feline ureteral stent placement is technically challenging and care should be taken before attempting this procedure in practice.

A new device called SUB (Figure 6) is currently under investigation for the treatment of feline ureteral obstructions when stent placement is either not possible or has failed. The placement of nephrostomy tubes, as described above, is useful when renal pelvic drainage is required. The biggest limitation is the externalized drainage, requiring careful management and hospitalization to prevent infection and dislodgement. The development of an indwelling ureteral bypass device using a combination of locking-loop nephrostomy and locking-loop cystostomy catheters allows a nephrostomy tube to remain indwelling. In people, a different type of ureteral bypass has been demonstrated to improve the quality of life and reduce the complication rates when compared with externalized nephrostomy tubes, and have remained in situ long term when compared with the chronic encrustations seen with indwelling ureteral stents. 47,48

This device is placed with fluoroscopic and surgical assistance using a similar Seldinger technique as described above for surgical nephrostomy tube placement. Once a nephrostomy and cystostomy tube are in place a nephropexy and cystoectomy are performed and both catheters are carefully tunneled under the skin and attached to a special port. Once both catheters are secured to the port system the device is tested by flushing it with contrast material under fluoroscopic guidance ensuring no leakage is present. Finally, the port is secured to the ventral body wall to prevent migration or dislodgement. It is

**Figure 6:** The placement of a subcutaneous ureteral bypass (SUB). (A) A lateral radiograph of a cat with a unilateral SUB and a contralateral ureteral stent. There is a nephrostomy catheter and cystostomy catheter connected to a vascular access port SC using a male-to-male adaptor port (white arrow). (B) Surgical picture of the SUB that is being secured SC to the port (yellow arrow). (C) Injection of the SUB using fluoroscopic guidance through the SC port (white). Notice a Huber needle being used to inject the port resulting in a nephrogram, cystogram and ureterogram. Because of contralateral stent patency there is contrast filling the contralateral renal pelvis.
important to remember that this device can be accessed in the future for either sampling or flushing the system, and this should only be done using a Huber needle. Care should be taken in performing a cystocentesis and that this should never be performed from the side of the SUB and should only be performed using ultrasound guidance. The need for SUB flushing through the port is rarely necessary, but can be performed using a 22-G Huber needle. The skin over the port should be clipped of fur and aseptically prepared. A Huber needle on an extension set with a 3-way stopcock is used with 1 empty syringe for urine sampling and 1 syringe filled with 50% contrast material. Under fluoroscopic guidance the port can be flushed and evacuated to ensure no encrustation is present and full patency is maintained (Figure 6).

The author has performed this procedure in 20 cats to date for various reasons, most commonly for proximal ureteral strictures. In a recent abstract all patients were assessed for patency, and with median follow-up period of 1 year, all were deemed patent and all patients had a decrease in the creatinine concentration. No SUB was seen to encrust or obstruct and they were well tolerated. With this procedure there were a few peri-operative complications including nephrostomy site leakage due to the breakdown of the nephropexy, leakage at the junction of 1 catheter to the port, and SUB occlusion with a blood clot, which was relieved with the infusion of 1 mg of tissue plasminogen activator. Leaking catheters were able to be salvaged by securing the catheter with stronger suture material (3-0 polydioxonone) and sterile tissue glue. With this adaptation no further leakage has been documented in cases thus far. To this point there were no short- or long-term complications in this small patient population. Overall, the use of a SUB for cats with a ureteral obstruction can be considered a functional option when other traditional therapies have failed or are contraindicated. The author considers this a salvage procedure as complications are not common, but can be severe if they occur and are typically procedure related. Further investigation into the use of this device in both cats and dogs is underway.

After placement of any device a 2-week course of a broad spectrum antimicrobial therapy is typically recommended. Routine urinary tract ultrasonography and radiography focusing on the renal pelvis diameter, stent location, ureteral diameter, and SUB catheters are performed to assure there is no evidence of migration, occlusion, or encrustation. Bacterial urine cultures should be obtained every 3 months for the first year then every 6 months thereafter. Based on guidelines in people, ureteral stents are traditionally meant to be removed whenever possible and this has been extrapolated to veterinary medicine as well. This is often the case for dogs but not cats. Long-term complications with ureteral stenting in both dogs and cat, if they occur, are typically minor, and should be anticipated and monitored for.

Extracorporeal shock-wave lithotripsy is another minimally invasive alternative for the removal of ureteral calculi. ESWL delivers external shockwaves through a water medium directed under fluoroscopic guidance in 2 planes. The stone is shocked anywhere from 1,000 to 3,500 times at different energy levels to allow for implosion and powdering. The debris is then left to pass down the ureter into the urinary bladder over a 1–2-week period (Figure 7). This procedure can be performed safely for ureteroliths smaller than 5 mm in dogs and 3–5 mm in cats. For larger stone burdens an indwelling double pigtailed ureteral stent is placed before ESWL to aid in stone debris passage, ureteral imaging, and immediate relief of the ureteral obstruction. For stones of larger sizes, or those imbedded in the ureteral mucosa, other minimally invasive options like a PCNUL may be necessary.

PCNUL is a minimally invasive procedure where an antegrade nephroureteroscopy is performed via renal access. The endoscope is advanced over a guide wire, down the ureter and ureteroscopic evaluation is performed. If a stone is present a stone basket can be used to remove the stone through the access sheath, or broken with the laser lithotrite. This is rarely necessary in veterinary medicine.

Ureteroscopy is possible in dogs larger than approximately 20 kg. This procedure is difficult to perform in dogs through a normal ureteral orifice, as the ureter in a normal dog is <2 mm and the smallest ureteroscope is approximately 2.5 mm. Ureteral access is obtained via cystoscopy, as described above with a guidewire being advanced into the renal pelvis (Figure 8). The flexible ureteroscope is then advanced over the guidewire into the ureter under fluoroscopic and endoscopic guidance. Once the cause of the obstruction is identified it can then be treated appropriately (eg, laser lithotripsy for stone disease or balloon dilation for a ureteral stricture).

Postoperative management: Postoperative care is critically important in patients with ureteral obstructions. All patients should be monitored carefully. Cats are at particularly high risk of developing severe post-obstructive diuresis (sometimes exceeding >100 mL/h of urine production) and therefore are at a high risk for fluid overload. In the author’s experience, the majority of patients that develop congestive heart failure after their procedure (usually 2–5 d later) have a normal echocardiogram before anesthesia. For this reason all cats are treated as if they have heart disease, or at a high
risk of fluid overload, and are monitored with central venous pressures, serial body weights, and urine output measurements to ensure they are not becoming fluid overloaded. The fluid rate is kept as conservative as possible to ensure proper hydration, cardiovascular stability, and improving azotemia. Care is taken to maintain an appropriate fluid balance using enteral hydration when possible (ie, via feeding tubes). Our recommendation is to place an esophagostomy tube in all cats with ureteral obstruction during their decompressive procedure. They are maintained on enteral water, if tolerated, during hospitalization at 60–120 mL/kg/d. If the urine production is above this rate then they are given 0.45% saline with 2.5% dextrose at 60 mL/kg/d IV. If the urine production exceeds the combination of this volume then they are further matched with a balanced electrolyte replacement fluid. Electrolyte and creatinine concentrations are followed carefully to prevent the development of hyponatremia. As long as the patient is cardiovascularly stable, and

Figure 7: Extracorporeal shock wave lithotripsy (ESWL) in a dog with multiple ureteroliths. (A) The ESWL machine with the dog in lateral recumbency under general anesthesia. The dry lithotrite is sitting above the dog’s ureter. (B) A lateral radiograph of the calcium oxalate ureteroliths before ESWL. (C) A lateral radiograph after a ureteral stent and ESWL was performed. Notice the ureteral stent traveling from the renal pelvis, down the ureter, and into the urinary bladder preventing a ureteral obstruction as the ureteroliths fragment and pass.

Figure 8: Retrograde ureteroscopy in a female dog. (A) Using cystoscopic guidance the ureter is cannulated with a guidewire and ureteral catheter for a retrograde ureteropyelogram. (B) A guidewire (black arrows) is up the ureter as a ureteral dilator (white arrowhead) is advanced over the guidewire to aid in acceptance of the ureteroscope. (C) Ureteral dilator traveling up the ureter (white arrow). (D) Ureteroscope (white arrows) that is up the ureter and inside the renal pelvis.
the creatinine is continually declining, then the author’s recommendation is to try and keep the patient fluid intake slightly under the estimated or quantified urine output (3–5%) to prevent overhydration. These recommendations are based on the author’s experience as currently, there is no evidence-based literature to formulate a treatment protocol.

**Follow-up management:** Persistent azotemia is a widespread problem after a successful intervention (over 40–50% of cats and 25–50% of dogs) and careful monitoring for renal disease progression, reobstruction, urinary tract infections, hypertension, hyperphosphatemia, and device malfunction is necessary. Fortunately, the persistent azotemia is typically within the IRIS Stages 1–2 chronic kidney disease, allowing a relatively long survival time. Initial reevaluation after an intervention is typically at 1–2 week intervals, then at 1 month, and every 2–3 months thereafter for 1–2 years, then every 6 months thereafter. Typical evaluation entails a CBC, biochemical profile, thyroid hormone concentration (cat), urinalysis, urine bacterial culture, urine protein: creatinine ratio (cats), blood pressure, abdominal radiograph, and abdominal sonography focusing on the urinary tract. Appropriate management of CKD is often necessary and may involve diet changes, the use of phosphorus binders, antacids, potassium citrate (for calcium oxalate stone formers), and angiotensin-converting enzyme inhibitor if proteinuria is present.

**Prognosis:** The prognosis for renal recovery and persistence of patency after a ureteral obstruction is relieved is variable depending upon the chronicity of the obstruction, the species, the cause for the obstruction, the method of fixation, the degree of obstruction, and the postoperative care. Considering the data in normal dogs demonstrate a dramatic loss of renal function within 7 days and little recovery is seen after 40 days, timing appears to be critically important for renal recovery and a ureteral obstruction should be treated as an emergency. The data also suggest that recovery can take weeks to months to occur, so being patient and giving the kidney time for recovery is necessary.

The author has noted dramatic improvements in creatinine concentrations 4–6 months after ureteral decompression. The resolution of hydroureter and hydronephrosis is typically observed quickly after resolution of the obstruction and should be followed routinely. Interestingly, in the over 75 cats that had ureteral stents placed in the author’s practice, only 5% of them did not experience a dramatic return of renal function. There was no clear documented risk factor (eg, renal pelvis size, kidney size, renal Doppler flow on ultrasonography, presence of anemia, degree of azotemia, chronicity of obstruction) that was predictive of renal outcome and ultimate stable creatinine concentrations in this large group of cats.

In the 16 dogs reported after surgical management of ureteral calculi the median survival time was 904 days (range 2–1,876) and the mortality rate was 25%. An additional 2 dogs required a second surgery. With the advent of ESWL for canine ureteroliths the outcomes are superior in the limited number of cases reported with an extremely low morbidity and mortality rate. In one study of 32 dogs with renal or ureteral calculi there was a 90% success rate, although 30% of dogs required more than 1 ESWL treatment. In the author’s experience, with concurrent ureteral stenting, <15% of dogs required a second treatment.

In the 153 cats reported, of which 89 had a surgical intervention and 52 had medical management alone, there was an approximately 30% major postoperative complication rate (eg, leakage, stricture, reobstruction) and approximately 20% peri-operative mortality rate. Thirty-three percent of cats treated medically died within 1 month of hospitalization. The mortality rate was as high as 39% for those patients requiring hemodialysis or a nephrostomy tube placement before surgery. Postoperatively 40% of cats had a ureteral obstruction recurrence, and 86% of these cats had nephroliths at the time of the first surgery, suggesting that nephrolithiasis could predispose patients to future ureteral obstructions.

The current recommended treatment in our practice is ESWL for dogs with ureteral obstructions (with or without a concurrent ureteral stent) and a ureteral stent in cats if they have concurrent nephroliths, multiple ureteroliths, are considered a poor surgical candidate, or have a history of previous stone surgery. These options are associated with the lowest morbidity and mortality rates to date. For cats with ureteral strictures, particularly those at the ureteropelvic junction, a SUB is typically recommended if traditional surgical treatment is declined.

**Conclusions**

The ureter is a frustrating area to gain access to for both diagnostic and therapeutic purposes. With the recent advances in veterinary interventional endourologic techniques, diagnosis and treatment has become less invasive and can often take place simultaneously. Proper training and the availability of specialized equipment is required to help these procedures become more available in the future. With these new modalities in veterinary medicine, it is hoped that better alternatives for these problematic conditions will be identified, as has been the case in human medicine. Ureteral diversion is the current treatment of choice in human medicine and is becoming similar in our prac-
tice as well. It is important to remain cognizant that much of the data in this review are still largely considered investigational but the future for these techniques clearly holds great promise.

Footnotes

7. Omnipaque, Iohexol 240mg/mL, GE Healthcare, Princeton, NJ.
8. Infiniti 6-Fr Locking loop drainage catheter, Infiniti Medical LLC, Malibu, CA.
9. Davson Meuller 5-Fr Locking loop drainage catheter, Cook Medical, Bloomington, IN.
10. Disposable Trocar Needle, 18-G x 15 cm, Cook Medical.
11. Angle-tipped hydrophilic 0.035 in. guidewire, Infiniti Medical LLC.
12. Stent, Double pigtail Ureteral stent, Infiniti Medical LLC.
13. Open-ended ureteral catheter, Cook Medical.

References


