Ureteral obstruction results in serious clinical signs in veterinary patients and requires prompt intervention for preservation of renal function. However, traditional surgical treatments (eg, ureterotomy, neoureterocystostomy, pyelotomy, and ureteroureterostomy) have been associated with high morbidity and mortality rates,

1–11 and alternative, minimally invasive techniques are currently considered the standard of care in human medicine. In addition, complications associated with traditional surgical treatments, such as ureteral stricture, failure to remove all urolith fragments, uroabdomen, progressive renal azotemia, septic peritonitis, and recurrent urolithiasis, can lead to recurrent ureteral obstruction, which may necessitate additional surgical procedures, including ureteronephrectomy, and progressive loss of renal function.

1–3,10,11,12 Extracorporeal shockwave lithotripsy, a less invasive treatment that may be associated with a lower risk of stricture formation and lower perioperative morbidity and mortality rates, has been reported\textsuperscript{13} as an effective treatment for ureteral obstructions in dogs. However, multiple treatments may be necessary, and recurrent obstruction is possible with stone fragmentation and continued stone formation.\textsuperscript{13} Lithotripsy is also not widely available for veterinary patients and is only appropriate for ureterolith-induced obstructions, versus other benign causes of obstruction such as ureteral strictures.

Minimally invasive (ie, endoscopic and fluoroscopic) placement of a double-pigtail ureteral stent can provide immediate relief of ureteral obstruction without the need for ureter surgery and its attendant risks and can often be performed as an outpatient procedure. The primary goal of double-pigtail ureteral stenting is to divert urine from the renal pelvis into the bladder, bypassing...

**Objective**

To describe the technique and short- and long-term outcomes for dogs undergoing double-pigtail ureteral stent placement for treatment of benign ureteral obstruction.

**Design**

Retrospective case series.

**Animals**

44 dogs (57 ureters).

**Procedures**

Medical records of dogs that underwent ureteral stenting for treatment of benign ureteral obstruction between 2010 and 2013 were reviewed. Signalment, history, pertinent diagnostic imaging results, endourologic and postprocedural details, duration of hospitalization, complications, and outcome (short term, 7 to 30 days; long term, > 30 days) were recorded. Ureteral stent placement was performed endoscopically, surgically, or both, with fluoroscopic guidance.

**Results**

57 ureters (44 dogs) underwent stenting because of obstructive urolithiasis (n = 48 [84%]), stricture (5 [9%]), or both (4 [7%]). Endoscopic or surgical techniques were successful for stent placement in 45 of 55 and 12 of 12 ureters (34/42 and 10/10 dogs), respectively. Median hospitalization time was 1 day. Median creatinine concentration was 2 mg/dL prior to stenting and 1.3 mg/dL 3 months after the procedure. Urinary tract infections were present in 26 of 44 (59%) dogs prior to stenting and in 11 of 43 dogs (26%) after stenting. One of the 44 (2%) dogs died after undergoing stenting, but the cause of death was not related to the procedure. Median follow-up time was 1,158 days (range, 3 to > 1,555 days), with 30 of 44 dogs alive at the time of last follow-up.

**Conclusions and Clinical Relevance**

Results suggested that ureteral stenting may be a viable option for first-line treatment of dogs with benign ureteral obstruction. However, patients should be monitored for urinary tract infection following stenting. (J Am Vet Med Assoc 2018;252:721–731)
ing the obstruction and allowing for decompression of the renal pelvis. However, stent placement may also encourage passive ureteral dilation, which could potentially decrease the risk of recurrent obstruction, aid in passage of uroliths, and facilitate future ureteroscopy. Also, stenting eliminates the risk of postoperative urine leakage that can occur following surgical methods for relieving ureteral obstructions, such as ureteral resection and anastomosis. Finally, placement of a double-pigtail ureteral stent can prevent migration of nephroliths into the ureter, which could result in subsequent ureteral obstructions.

Our group has previously reported on the use of double-pigtail ureteral stenting for the treatment of 12 dogs with malignant ureteral obstructions, a single dog with congenital bilateral ureteral stenosis, and 13 dogs with obstructive pyonephrosis. Additionally, ureteral stenting has been found to be an effective treatment for benign ureteral obstructions in cats. However, we are not aware of published information on the short- and long-term outcomes of ureteral stenting for the treatment of benign ureteral obstructions in dogs. Thus, the objectives of the study reported here were to describe the procedure for double-pigtail ureteral stent placement in dogs and document short- and long-term outcomes for a series of dogs that underwent double-pigtail ureteral stenting for treatment of benign ureteral obstruction. We hypothesized that ureteral stent placement would be a safe and effective method for maintaining ureteral patency in dogs with benign ureteral obstruction and that stents could typically be placed in a minimally invasive (ie, nonsurgical) manner.

Materials and Methods

Case selection criteria and medical records review

Medical records of dogs evaluated by the Interventional Radiology and Endoscopy Service of the Animal Medical Center, New York, between February 1, 2010, and August 31, 2013, with a diagnosis of benign ureteral obstruction (ie, ureterolithiasis, ureteral stricture, or inspissated purulent material) in which a ureteral stent was placed by 1 of 2 authors (ACB and CWW) were reviewed. Dogs were included only if a minimum of 6 months of follow-up information was available (if dogs were still alive). Dogs were excluded if stents were placed for treatment of malignant ureteral obstruction or trauma or to assist in postsurgical healing or if the medical record was incomplete (ie, a procedure report was not available).

Data recorded from the medical records of dogs included in the study consisted of history; signalment; body condition score (on a scale from 1 to 9); results of diagnostic imaging (eg, ultrasonography, radiography, and pyelography); results of serum biochemical analyses and urinalyses (including results of bacterial culture and susceptibility testing, as applicable); procedural details; duration of hospitalization; immediate postoperative (< 7 days), short-term (7 to 30 days), and long-term (> 30 days) complications (as applicable); and short-term (≤ 30 days) and long-term (> 30 days) outcome. Outcome data included results of repeated physical examinations and laboratory testing. Minor complications were those that resolved with medical management alone or did not require treatment. Major complications were those that led to death or required another intervention for resolution. In particular, complications that led to the stent no longer being functional (ie, occlusion of the ureter reoccurred) were considered major. If this occurred, 6 options presented themselves for treatment: exchange of the stent for a new stent, placement of a second stent next to the first stent to create a sieve effect, placement of an SUB device, ureteral surgery (eg, ureteral reimplantation, ureterotomy, or ureteral resection and anastomosis), removal of the stent, and allowing the stent to remain in place while monitoring kidney and ureter function.

Information on IRIS stage for each dog was also retrieved from the medical records. Patients assigned IRIS stage 0 were nonazotemic with a serum creatinine concentration within reference limits (ie, < 1.5 mg/dL) and urine specific gravity > 1.030. Stage 1 patients were nonazotemic but with a urine specific gravity < 1.030. Stage 2 patients had mild azotemia (creatinine, 1.5 to 2.0 mg/dL), stage 3 patients had moderate azotemia (creatinine, 2.1 to 5 mg/dL), and stage 4 patients had severe azotemia (creatinine, > 5 mg/dL). The diagnosis of a benign ureteral obstruction was made on the basis of results of abdominal ultrasonography, abdominal radiography, and fluoroscopic-guided ureteropyelography, as previously reported.

Preoperative evaluation

Prior to stenting, patients underwent transabdominal ultrasonography, abdominal radiography, and, if a heart murmur or arrhythmia was present, thoracic radiography with or without echocardiography. An ultrasonographic diagnosis of ureteral obstruction was made on the basis of signs of hydronephrosis and associated hydroureter in a region of the ureter that was either obstructed by a hyperechoic, shadowing structure (ie, suspected stone) or had an abrupt taper (ie, suspected stricture or other debris). Retrograde ureteropyelography was performed by means of cystoscopic or surgical catheterization of the ureterovesicular junction and fluoroscopic assistance; antegrade ureteropyelography was performed with ultrasonographic- or surgical-assisted renal puncture with fluoroscopic assistance. The appearance of a dilated renal pelvis and ureter proximal to an obstructive lesion on ureteropyelograms was considered diagnostic of ureteral obstruction (Figure 1). The presence and location of ureteral calculi, number and size of ureteral calculi, presence and number of nephroliths, and diameter of ureteral lesions and the renal pelvis (if applicable) were recorded. Renal pelvis diameter
Endoscopic stent placement was performed in patients with ureteral obstruction. Notice that the distal portion of the ureter is narrowed, but that the renal pelvis and proximal portion of the ureter are dilated, and that there is a filling defect caused by an obstructive ureterolith where the ureter abruptly narrows.

was obtained on a transverse transabdominal ultrasonographic image. Location of ureteral obstruction was classified as proximal third, middle third, distal third, or multiple locations.

Medical treatment
All patients had a preoperative CBC, serum biochemical analyses, urinalysis, and bacterial culture of a urine sample (with susceptibility testing as applicable). Preoperative use and duration of IV fluid therapy, α-adrenergic receptor blockers, diuretics, and antimicrobials was not standardized, because many patients had been referred specifically for minimally invasive treatment. However, all patients received enrofloxacin (15 mg/kg [6.8 mg/lb], IV, q 24 h), ampicillin with sulbactam (22 mg/kg [10 mg/lb], IV, q 8 h), or an appropriate alternative antimicrobial selected on the basis of results of bacterial culture and susceptibility testing prior to ureteral stent placement.

Procedures
The typical anesthesia protocol included premedication with oxymorphone (0.1 mg/kg [0.045 mg/lb], IM) and induction of general anesthesia with propofol (3 mg/kg [1.36 mg/lb], IV) or a combination of etomidate (1 to 2 mg/kg [0.45 to 0.9 mg/lb], IV) and midazolam (0.25 to 0.5 mg/kg [0.11 to 0.23 mg/lb], IV), followed by endotracheal intubation and maintenance of anesthesia with isoflurane in oxygen and a fentanyl constant rate infusion (0.35 to 0.7 µg/kg/min [0.16 to 0.32 µg/lb/min], IV). If hypotension occurred during anesthesia, dopamine (5 to 12 µg/kg/min [2.3 to 5.5 µg/lb/min]) was administered as a constant rate infusion. Once anesthetized, patients were positioned in dorsal recumbency. The abdomen and vulva or prepuce were clipped of hair and aseptically prepared, and the vulva or prepuce was lavaged with dilute chlorohexidine solution. The entire abdomen and vulva or prepuce were draped in standard fashion. If the patient was not currently receiving antimicrobial treatment with a spectrum that included gram-positive organisms, cefazolin (22 mg/kg [10 mg/lb], IV) was administered every 2 hours throughout the procedure.

In all patients, a multifenestrated double-pigtail polyurethane-type ureteral stent was placed with the proximal pigtail loop of the catheter coiled within the renal pelvis, the catheter shaft located in the lumen of the ureter, and the distal pigtail loop curled in the urinary bladder (Figure 2). In patients with pyonephrosis, renal pelvic lavage was performed prior to stent placement with an open-ended ureteral catheter, as described.

Female dogs—Endoscopic stent placement was performed with a 19-, 27-, or 4-mm 30° rigid cystoscope and fluoroscopic guidance. Once the ureterovesical junction was identified, an appropriately sized (0.018- or 0.035-inch) angle-tipped hydrophilic guide wire was advanced into the distal portion of the ureter. An appropriately sized open-ended ureteral catheter (3 to 5F) was then advanced over the guide wire into the distal portion of the ureter. The guide wire was then removed, and a urine sample was obtained, if possible. Retrograde ureteropyelography was performed with a 1:1 mixture of iohexol and sterile (0.9% NaCl) saline solution (typical volume, 1 to 2 mL) with fluoroscopic guidance to aid in identification of lesions, stones, and other filling defects; delineate the obstructed portion of the ureter; and locate the renal pelvis. Once ureteropyelography was completed, the guide wire was reintroduced via the ureteral catheter and advanced into the renal pelvis by carefully advancing it around the obstructive lesion. The wire was then coiled inside the renal pelvis, and the ureteral catheter was advanced over the wire to the renal pelvis. This catheter was then used to drain the renal pelvis and obtain a urine sample for cytologic analysis and bacterial culture and susceptibility testing. Then, the catheter was withdrawn over the guide wire, maintaining access by means of the wire located in the renal pelvis. The ureteral length was measured during withdrawal from the ureteropelvic junction to the ureterovesical junction. The ureteral catheter was then removed over the guide wire, and an appropriately sized ureteral stent (2.5F, 3.7F, 4.7F, or 6F and 12 to 30 cm in length) was advanced over the
guide wire into the renal pelvis. Once the proximal pigtail loop was coiled within the renal pelvis, the guide wire was withdrawn, and a pushing catheter of the stent system was used to advance the distal end of the stent into the urinary bladder.

Male dogs—In male dogs weighing > 7 kg (15.4 lb), a technique similar to that described for female dogs was used, except with a flexible cystoscope, rather than a rigid cystoscope. In these patients, the urethra and urinary bladder could accommodate the flexible cystoscope, enabling cannulation of the ureterovesicular junction. However, the ureteral catheter and ureteral stent would not fit through the working channel of the flexible cystoscope; therefore, stent placement required use of a stiffened angle-tipped hydrophilic guide wire for cannulation of the ureter, followed by removal of the endoscope off the wire for catheterization and stent placement under fluoroscopic guidance alone.

In dogs in which retrograde cystoscopy was not possible, an alternative minimally invasive approach
was performed, consisting of antegrade percutaneous cystoscopy from the bladder apex, percutaneous perineal access into the ischial urethra followed by serial dilatation and rigid cystoscopy, or percutaneous ultrasound-guided access through the renal pelvis under fluoroscopic guidance.

**Surgical approach**

In dogs in which minimally invasive placement of ureteral stents was not feasible, a ventral midline laparotomy was performed in conjunction with 1 of the following 5 methods: a retrograde approach through the ureterovesicular junction, a retrograde approach through a ureterotomy incision, an antegrade approach with concurrent ureteral resection and anastomosis, a retrograde approach with concurrent ureteral reimplantation, or an antegrade approach by means of fluoroscopically guided nephrostomy and ureteropyelography. Open retrograde stent placement was performed as described for the endoscopic approach except that access to the ureterovesicular junction was obtained surgically via a caudoventral cystotomy. Magnification was often necessary to cannulate the ureterovesicular junction with the guide wire and open-ended ureteral catheter. A ureterotomy was performed if the guide wire could not be advanced past the obstructive lesion. When necessary, the guide wire and catheter were placed through the ureterotomy site in an antegrade manner into the urinary bladder. Once this was achieved, the wire was turned around within the catheter so that the angled end of the guide wire was leading and passed up the catheter, within the ureter. The guide wire was then advanced up the ureter to the renal pelvis, and the catheter was advanced over the wire. Ureteropyelography was performed to confirm location within the renal pelvis, after which the catheter was removed over the wire, and an appropriately sized stent was placed. The ureterotomy incision was then closed over the stent under magnification with 6-0 or 8-0 polyglycolic acid 910 in a simple interrupted pattern. Rarely, if the ureter was damaged by obstructive urolithiasis or a stricture such that a stent could not be passed, the affected portion of the ureter was resected, and the ureter was anastomosed with 6-0 or 8-0 polyglycolic acid 910 in simple interrupted pattern or the ureter was reimplanted in the apex of the bladder with 8-0 polyglycolic acid 910 in a simple interrupted pattern. A guide wire and stent were then advanced through the ureter to the renal pelvis, if indicated. For all patients undergoing a cystotomy, the bladder incision was closed with 3-0 or 4-0 poliglecaprone 25 in a simple interrupted, continuous, or cruciate pattern.

All procedure times (from the start of cystoscopy or the start of the ventral midline incision to the completion of cystoscopy or closure of the abdomen) were recorded. Anesthesia times were also recorded. After stents were placed, cystography with concurrent ureteropyelography was performed to confirm patency of the ureter and stent and to assess for any ureteral leakage. All laparotomy incisions were routinely closed in 3 layers. An esophagostomy tube was occasionally placed after surgery to aid in enteral fluid therapy and maintain nutrition in patients with severe azotemia or prolonged inappetence.

**Postoperative management**

All patients were carefully monitored for hydration status on the basis of serial measurements of body weight, serum electrolyte concentrations, total solids concentration, and PCV. Antimicrobials were prescribed as described. Enrofloxacin (15 mg/kg, IV or PO, q 24 h) was also administered for a minimum of 2 weeks. If results of bacterial culture were positive, treatment with an appropriate antimicrobial was continued for 6 weeks. Postoperative analgesia was provided in accordance with clinician preference.

**Follow-up**

At each recheck examination, body weight, PCV, and total solids concentration were measured and serum biochemical analyses, a urinalysis, bacterial culture of a urine sample, abdominal radiography, and urinary tract ultrasonography were performed. Recounting 2 weeks, 6 weeks, 3 months, 6 months, 9 months, and 12 months after discharge and then every 3 to 6 months thereafter was recommended. If calcium oxalate stones were documented on the basis of results of stone analysis or suspected on the basis of negative results of urine bacterial culture and a low urine pH (eg, < 7.0) with radiopaque stones, long-term treatment with potassium citrate (75 mg/kg [34 mg/lb], PO, q 12 h) was recommended, and urine pH and serum potassium concentration were monitored. Long-term feeding of a renal diet was recommended for patients that were persistently azotemic; for patients with a creatinine concentration in the reference range, a stone-neutralizing or, when appropriate, stone-dissolving diet was recommended. Specific aspects of long-term medical management were tailored for each patient. For patients suspected to have had magnesium ammonium phosphate stones on the basis of results of stone analysis, high urine pH (eg, > 7.0), and culture of urease-producing bacteria (eg, *Staphylococcus* spp or *Proteus* spp), long-term antimicrobial treatment and feeding of a stone-dissolving diet were strongly encouraged. Careful monitoring by means of repeated diagnostic imaging to monitor for stone dissolution around the stent and in the renal pelvis was performed. When stone dissolution was evident, antimicrobial treatment was discontinued, and serial urine samples were submitted for bacterial culture.

Follow-up time varied. If the patient died, the cause of death was recorded, when available, and categorized as renal, likely renal, unlikely renal, not renal, or unknown. A renal cause of death was suspected if creatinine concentration was high and had increased prior to death or euthanasia. Outcome information was obtained from owners or referring veterinarians.
Statistical analysis

Continuous variables were summarized as mean and SD for normally distributed variables and as median and range for nonnormally distributed variables. Categorical variables were analyzed by means of \( \chi^2 \) analyses or the Fisher exact test (if expected value for any cell was < 5). 

Outcome was analyzed for all patients and for patients grouped on the basis of IRIS stage before and 1 to 6 months after surgery. Survival analyses were performed with Kaplan-Meier product limit estimates. Survival times included renal survival time (defined as time until stent removal) and patient survival time (defined as time until death or final follow up). Events (primary endpoints) for survival analyses included death, the need for stent exchange, stent removal, and whether an SUB device was placed. Risk factors for the need for stent exchange or SUB device placement were evaluated, including cause of obstruction (stone vs stricture), the presence of a urinary tract infection before ureteral stent placement, and stone type. The presence of preoperative urinary tract infection was evaluated for associations with development of complications (occlusion, encrustation, ureteritis, and proliferative tissue at the ureterovesicular junction), stone type, and postoperative urinary tract infection. Preoperative IRIS stage was also evaluated for associations with postoperative IRIS stage.

Strata were compared with a log-rank test. For univariate analyses, hazard ratios were calculated with a Cox proportional semiparametric regression model. Values of \( P < 0.05 \) were considered significant, and all analyses were performed with commercially available software.

Results

Forty-four dogs with 57 obstructed ureters that underwent stent placement for treatment of ureterolithiasis (57/44 [84%] dogs and 48/57 [84%] ureters), ureteral stricture (3/44 [7%] dogs and 5/57 [9%] ureters), or both (4/44 [9%] dogs and 4/57 [7%] ureters) met the study inclusion criteria. Twelve of 44 patients (12/57 ureters) had been included in a previous report involving obstructive pyonephrosis in dogs.

Thirty of the 44 dogs were spayed females, 10 were neutered males, 3 were sexually intact males, and 1 was a sexually intact female. There were 6 Bichon Frise, 5 mixed-breed dogs, 4 Yorkshire Terriers, 4 Shih Tzus, 2 Pomeranians, 2 Miniature Schnauzers, 2 Havanese, 2 Lhasa Apsos, 2 Chihuahuas, and 1 Portuguese Water Dog. Bernese Mountain Dog, Beagle, Miniature Poodle, English Bulldog, Maltese, Shetland Sheepdog, Standard Poodle, American Pit Bull Terrier, Chinese Pug, Borzoi, Jack Russell (Parson Russell) Terrier, Standard Schnauzer, and West Highland White Terrier. Median age at the time of stenting was 8.15 years (range, 1.0 to 15 years), and median body weight was 6.3 kg (13.9 lb; range, 1.3 to 40 kg [2.9 to 88 lb]). Median body condition score was 5 (range, 1 to 9). A heart murmur was detected in 17 of 44 (39%) dogs with a median murmur grade of 2/6.

Pertinent history included unilateral nephrectomy in 2 the 44 (5%) dogs, azotemia in 31 (70%; duration of azotemia, 1 to 150 days), and cystotomy for bladder stones in 13 (30%). Other historical findings included decreased appetite (26/44 [59%]), weight loss (5/44 [11%]), vomiting (20/44 [45%]), polyuria and polypydipsia (12/44 [27%]), stranguria (14/44 [32%]), hematuria (11/44 [25%]), and diarrhea (11/44 [25%]). Thirty-two (73%) dogs had a documented median duration of ureteral obstruction of 5.5 days (range, 1 to 60 days), as determined by previous abdominal ultrasonography.

Two of 7 dogs (2/9 ureters) with stricture-induced ureteral obstruction had a history of a previous surgery on the ipsilateral ureter. One of these dogs had a history of inadvertent ureteral ligation at the time of ovariohysterectomy followed by ureteral reimplantation; the other had a history of abscess formation in the lateral ligament of the bladder secondary to bladder rupture that had resulted in a ureteral stricture. The other 5 dogs with ureteral strictures (7 ureters) had no known inciting cause.

Clinicopathologic findings

On initial evaluation, the median PCV was 40% (range, 25% to 58%; reference range, 38.3% to 56.5%). Four of 44 (9%) dogs were anemic at the time of admission, and 13 (30%) had low platelet counts. Median platelet count for all dogs was 212,000 platelets/\( \mu \)L (range, 40,000 to 654,000 platelets/\( \mu \)L; reference range, 143,000 to 448,000 platelets/\( \mu \)L). Median BUN concentration was 24.5 mg/dL (range, 8 to 224 mg/dL; reference range, 9 to 31 mg/dL), median creatinine concentration was 2 mg/dL (range, 0.6 to 14.9 mg/dL; reference range, 0.5 to 1.5 mg/dL), and median IRIS stage was 1.5 (range, 0 to 4), with 23 of 44 (52%) dogs having azotemia (creatinine, > 1.5 mg/dL) at the time of initial evaluation. Median sodium concentration was 145 mEq/L (range, 131 to 156 mEq/L; reference range, 142 to 152 mEq/L), median potassium concentration was 4.3 mEq/L (range, 3.4 to 5.7 mEq/L; reference range, 4 to 5.4 mEq/L), and median phosphorus concentration was 4.3 mg/dL (range, 1.8 to 24 mg/dL; reference range, 2.5 to 6.1 mg/dL). Median urine specific gravity was 1.020 (range, 1.006 to 1.042; reference range, > 1.030), with isosthenuria present in 8 of 44 (18%) dogs. Median urine pH was 6.5 (range, 5.5 to 8; reference range, 6 to 7.5).

Twenty-six of 44 (59%) dogs were determined to have, on the basis of bacterial culture of a urine sample, a urinary tract infection prior to stent placement. Results of bacterial identification were available for 25 of the 26 (96%) dogs, and included Escherichia coli (n = 10), Staphylococcus spp (9), Klebsiella spp (2), Enterococcus spp (1), Enterobacter spp (1), Pseudomonas spp (1), and Proteus spp (1).

Diagnostic imaging

Results of abdominal radiography and transabdominal ultrasonography were available for review for all 44 dogs. Nephroliths were evident in 28
of 57 (49%) kidneys ipsilateral to the obstructed ureter; 20 of 31 (65%) dogs with unilateral ureteral obstruction had evidence of nephrolithiasis in the contralateral (nonobstructed) kidney. Ureteroliths were evident in 5 of 31 (16%) contralateral (nonobstructed) ureters.

Twenty-six of 44 (59%) dogs had evidence of bladder stones. Median number of stones identified in the affected ureter radiographically was 1 (range, 0 to > 3); median number identified ultrasonographically was also 1 (range, 0 to 6). Three of 52 (6%) ureters had no evidence of stones on radiography or ultrasonography but had stones identified at the time of stent placement by means of ureteropyelography.

The obstruction was considered unilateral in 31 of 44 (70%) dogs and bilateral in 13 (30%), with the left ureter affected in 30 dogs and the right ureter affected in 27 dogs. On the basis of transverse renal ultrasonography, median renal pelvis diameter was 15.0 mm (range, 2 to 70 mm). Hydroureter was identified in 37 of the 57 (65%) ureters proximal to the obstructive lesion, with a median ureteral diameter of 6 mm (range, 2 to 110 mm). Ureterolith location was recorded for 34 ureters; it was in the proximal third of the ureter in 14 (41%), the middle third in 6 (18%), and the distal third in 10 (29%) and in multiple locations in 4 (12%).

On the basis of results of diagnostic imaging and surgical exploration, the cause of the ureteral obstruction was considered to be ureterolithiasis alone in 48 of 57 (84%) ureters, a ureteral stricture alone in 5 (9%), and a combination of stricture and stone in 4 (7%). The diagnosis of ureteral stricture was based on evidence of a focal ureteral obstruction without evidence of a ureterolith at the site and with ureteropyelographic findings of blunted narrowing without evidence of an intraluminal filling defect, as described.3,9,10 No circumcaval ureters were identified. Radiography was able to correctly identify ureteroliths in 28 of the 52 (54%) ureters; abdominal ultrasonography was able to correctly identify ureteroliths in 41 (79%).

Medical management

Intravenous fluid therapy was administered for a minimum of 1 day (median, 2 days; range, 1 to 10 days) in 29 of the 44 (66%) of dogs prior to stent placement. In the remaining dogs, fluids had not been administered prior to initial examination at our hospital. In these dogs, IV fluid therapy was instituted at the time of hospital admission, but the procedure took place within 24 hours after admission. Antimicrobial treatment was instituted prior to the procedure in 34 of the 44 (77%) dogs and was continued intra- and postoperatively in all dogs.

Ureteral stenting procedure

Stents were successfully placed in all 57 (100%) ureters. Minimally invasive endoscopic techniques were successful for 45 of 55 (82%) ureters (34/42 [81%] dogs) in which they were attempted, and surgical assistance was used successfully in 12 of 12 (100%) ureters (10/10 dogs). A surgical approach was performed without an initial cystoscopic attempt in 2 dogs. Overall median procedure time was 65 minutes (range, 24 to 280 minutes).

Endoscopic approach with fluoroscopic assistance

For 55 ureters (42 dogs), an endoscopic technique was attempted for ureteral stent placement and was successful for 36 of 41 (88%) ureters in female dogs and 9 of 14 (64%) ureters in male dogs. Retrograde cystoscopy alone was used for 39 of the 45 (87%) ureters for which minimally invasive techniques were successful, percutaneous antegrade cystoscopy was used for 4 (9%), and percutaneous antegrade nephrostomy and perineal access were each used for 1 (2%). Median minimally invasive procedure time was 60 minutes (range, 24 to 225 minutes).

Surgical approach

For 12 ureters (10 dogs), a surgical technique was used for stent placement and was successful in all 12 (10 ureters for which minimally invasive techniques had been unsuccessful and 2 ureters for which minimally invasive techniques were not attempted). Stent placement was accomplished by means of cystotomy and open retrograde catheterization of the ureterovesicular junction in 5 of the 12 (42%) ureters, a combination of ureterotomy and cystotomy in 3 (25%), ureterotomy in 1 (8%), a combination of cystotomy and ureteral resection and anastomosis in 1 (8%), a combination of cystotomy and ureteral reimplantation in 1 (8%), and open antegrade pyelocentesis in 1 (8%). Median surgical procedure time was 113 minutes (range, 60 to 280 minutes).

Perioperative care

Stone type was analyzed for 22 of the 52 ureters (41 dogs) with ureterolithiasis and was predicted for the remaining 30 ureters. Thirty-two (62%) stones were calcium oxalate, 10 (19%) were struvite, 5 (10%) were calcium apatite or calcium phosphate, 4 (8%) were urate, and 1 (2%) was a calcium-based mixed-type stone. Stones that were analyzed were typically from the urinary bladder rather than the ureter. Stone type was predicted on the basis of results of urine bacterial culture and susceptibility testing, urine pH, crystalline material in the urine, response to medical dissolution, and a history of a specific stone type. Twelve of 44 (27%) dogs had an esophagostomy tube placed for enteral nutritional and water supplementation at the completion of the stenting procedure.

Serum creatinine concentration, BUN concentration, and PCV were recorded in all dogs after stenting and prior to hospital discharge (or death in 1 case); median values were 1.5 mg/dL (range, 0.8 to 7.9 mg/dL), 30 mg/dL (range, 8 to 109 mg/dL), and 35% (range, 28% to 54%), respectively. Median renal pelvis diameter, determined by means of transverse ultrasonography at the first recheck examination 7 to 30 days after stent placement, was 5.7 mm (range, 0.0 to 35 mm). Median hospitalization time for the 43
Complications

Major procedure-related complications occurred with 3 of the 57 (5%) obstructed ureters (3/44 [7%] dogs). One complication was a result of shearing of the outer coating of the guide wire within the stent, causing obstruction of the inner lumen of the stent and requiring endoscopic stent replacement. The second complication was a result of ureteral perforation with the ureteral catheter, which required conversion to surgery for stent placement. The third complication was a result of ureteral avulsion during endoscopic catheter placement, requiring open ureteral resection and anastomosis over a ureteral stent. There were 2 (4%) minor procedure-related complications that had no clinical effects on the patients: 1 instance of ureteral perforation with a 0.025-inch guide wire, and 1 instance of contrast extravasation at the ureteropelvic junction that was likely associated with guide wire perforation. Both leaks resolved with successful endoscopic stent placement and did not require further intervention.

Hematuria (9/44 [20%] dogs) was the only postprocedure (< 1 week) complication that was considered procedure-related, and resolved in all cases without intervention. In 6 dogs, hematuria resolved within 7 days, and in the remaining 3, it resolved within 1 month.

One dog died 3 days after stent placement; however, death was due to progression of sepsis that was present prior to stent placement and was not considered procedure-related. This dog had undergone surgical stent placement, and the entire urinary tract had been lavaged because of severe pyonephrosis. The ureter was not obstructed at the time of death.

The 43 dogs that survived ≥ 7 days after stent placement were assessed for short-term (1 week to < 1 month) complications, and complications associated with 7 of the 56 (13%) ureters were identified. Two of the 56 (4%) ureters experienced stent migration, which were considered major complications requiring endoscopic stent manipulation. The remaining 5 complications were minor and consisted of hematuria in 3 of 43 (7%) dogs, a minor body wall hernia after surgery in 1 (2%) dog, and development of urinary incontinence in 1 (2%) dog. Long-term complications (> 1 month or persistence of short-term complications) occurred in 20 of the surviving 43 dogs. These complications included urinary tract infection (11/43 [26%] dogs), occlusion of the ureteral stent (5/56 [9%] ureters), suspected ureteritis (3/56 [5%] ureters), proliferative tissue at the ureterovesical junction (3/56 [5%] ureters), ureteral stent migration (3/56 [5%] ureters), encrustation of the stent (1/56 [2%] ureters), and hematuria (3/43 [7%] dogs).

Stent exchange (7/56 [12%] ureters; 5/43 [12%] dogs) or replacement with an SUB device (2/56 [3.6%] ureters; 2/43 [5%] dogs) was necessary in 9 of 56 (16%) ureters and 7 of 43 (16%) dogs. In affected dogs, stent exchange was performed a median of 139 days after the original procedure (range, 4 to 617 days). This was necessary because of stent occlusion (n = 3), stent migration (1), or recurrent urinary tract infection (3). In 2 dogs (2 ureters), an SUB device was implanted 19 and 533 days after the original procedure without a previous attempt at stent exchange.

Positive results of bacterial culture of urine were documented in 26 of 44 (59%) dogs prior to stent placement and in 11 of 43 (26%) dogs > 1 month after stent placement. Of the 25 dogs with urinary tract infection prior to stent placement that survived to hospital discharge, 18 (72%) were ultimately able to clear the infection, but the remaining 7 (28%) experienced recurrent urinary tract infections that required multiple courses of antimicrobial treatment and were still undergoing treatment at the time of last follow-up. No dogs that did not have a urinary tract infection prior to stent placement developed an infection after stent placement.

Follow-up

Median creatinine concentration in dogs that survived was 1.3 mg/dL (range, 0.3 to 15.9 mg/dL) 3 months after stent placement, 1.2 mg/dL (range, 0.6 to 4.8 mg/dL) 6 months after stent placement, and 1.2 mg/dL (range, 0.5 to 16 mg/dL) at the time of last follow-up. Median IRIS stage was 0 (range, 0 to 4) both 3 and 6 months after stent placement. Median renal pelvis diameter on transverse ultrasonographic images obtained at the time of last follow-up was 4.0 mm (range, 0 to 30 mm).

Outcome

Forty-three of the 44 (98%) dogs survived to hospital discharge. Median follow-up time for all dogs was 1,158 days (range, 3 to 1,555 days), with 30 of 44 (68%) dogs still alive at time of last follow-up. Only 6 of 43 (14%) dogs ultimately died of suspected or confirmed progression of chronic kidney disease. No dogs died of complications related to the stenting procedure, renal failure, or known recurrent ureteral obstruction. However, not all dogs that died during the study period underwent a necropsy or follow-up ultrasonography.

In univariate analyses, the following factors were not significantly associated with outcome: obstructed ureter (right vs left vs both); cause of obstruction; preoperative WBC count, anemia, isosthenuria, thrombocytopenia, or urinary tract infection; and sex. Procedural factors, including procedure complications and esophagostomy tube placement, and postoperative variables, including perioperative and short-term complications and the need for stent exchange, were also not found to be significantly associated with outcome.

Factors significantly associated with outcome on the basis of univariate log-rank survival analysis were preoperative BUN concentration (P = 0.013), preoperative serum creatinine concentration (P < 0.001), preoperative IRIS stage (P < 0.001), and development
of long-term complications \(P = 0.035\). The hazard ratio for preoperative serum creatinine concentration was 1.36 (95% confidence interval, 1.167 to 1.594), indicating that for each 1 mg/dL increase in creatinine concentration, dogs were 36% more likely to die during the study period.

Factors potentially associated with the need for stent exchange or SUB device placement that were evaluated consisted of cause of obstruction (stone vs stricture), presence of urinary tract infection before stent placement, and stone type. The presence of urinary tract infection before stent placement was evaluated for association with development of complications (occlusion, encrustation, ureteritis, and proliferative tissue at the ureterovesicular junction), stone type, and urinary tract infection after stent placement. Preoperative IRIS stage was evaluated for an association with postoperative IRIS stage. The only significant risk factor for stent exchange or SUB device placement was stone type \(P = 0.016\), with an increased risk observed with calcium apatite or phosphate stones. Preoperative IRIS stage was also predictive of postoperative IRIS stage \(P = 0.007\). No other evaluated variables were significant.

Discussion

Results of the present study indicated that ureteral stenting may be a viable option for first-line treatment of dogs with benign ureteral obstruction. Ureteral stents were successfully placed in all 44 dogs (57 ureters) in the present study regardless of stone number, location of the obstruction, or etiology of the obstruction, and ureteronephrectomy was not needed in any dog. Short- and long-term complications were typically minor but did necessitate stent exchange or an alternative treatment such as placement of an SUB device in 7 of 43 (16%) dogs, representing 9 of 56 (16%) ureters. Median hospitalization time was 1 day, and 43 of 44 (98%) of dogs were discharged from the hospital.

Advanced diagnostic imaging such as contrast-enhanced CT was not used for diagnosis of ureteral obstruction in the present study. A combination of abdominal ultrasonography and radiography was typically performed, and the combination was highly accurate when compared with ureteropyelographic findings. Ultrasonographic findings of hydronephrosis and associated hydroureter in association with abdominal radiographic findings documenting the presence of stones were sufficient in most dogs with ureterolithiasis. These results were in agreement with results of a previous case series involving cats with ureteral obstruction.\(^5\) Ureteropyelography was useful in determining the underlying cause in dogs in which the cause of ureteral obstruction was not evident with standard diagnostic imaging. Transabdominal ultrasonography appeared to be more useful for detecting ureteroliths than abdominal radiography (diagnostic success for 41/52 [79%] vs 28/52 [54%] ureters, respectively); however, the combination of the 2 modalities offered additional information, including radiopacity of the stone material and location of the stones, and allowed for evaluation for concurrent bladder, urethral, and renal stones.

Stent placement was successful for all 57 ureters in present study; however, an open surgical approach to the abdomen was required for stent placement in 12. The need for surgery was associated with a large obstructive collection of ureteroliths that did not allow guide wire passage during attempted minimally invasive stent placement, preexisting retroperitoneal abscess formation requiring open debridement, perforation of the ureter during minimally invasive stent placement, or inability to access the ureter during retrograde cystoscopy. Endoscopic stent placement was technically easier in female than in male dogs but was successful in male dogs with increasing experience.

The high success rate of endoscopic stent placement in female dogs allowed for outpatient treatment in dogs without systemic complications. Our findings suggested that regardless of the location or cause of the ureteral obstruction, placement of a ureteral stent can be considered a viable option in most dogs, and perioperative morbidity and mortality rates in the present study were generally lower than rates associated with traditional surgical options.\(^2,3,10\) The most common long-term complication associated with ureteral stenting in the present study was a need for stent exchange or SUB device placement (9/56 [16%] ureters and 7/43 [16%] dogs) because of stent occlusion of the ureter, stent migration, or recurrent urinary tract infections. This compared favorably with the reported rate of ureteral stent placement in cats,\(^5\) and stent exchange was typically performed on an outpatient basis. More recently, we have begun in our practice to place dual stents side-by-side within a patient’s ureter in an effort to prevent stricture-induced recurrence of stent obstruction. This method is currently under further investigation.

In the present study, urinary tract infection was present in 26 of 44 (59%) dogs prior to stent placement and in 11 of 43 (26%) dogs > 1 month after stent placement, and 18 of 25 (72%) dogs with preoperative urinary tract infection that survived to hospital discharge were eventually able to clear the infection. However, the presence of infection was not associated with outcome or development of long-term complications in the present study. As previously reported,\(^5\) the presence of a stent may contribute to infection persistence. However, we speculate that the high percentage of dogs with preoperative urinary tract infection suggested that these patients had a predisposition to infections that was not specifically related to the stenting procedure, and that this predisposition might explain why many of the patients had struvite or calcium phosphate ureterolithiasis.

Twenty-three of 44 (52%) dogs in the present study had azotemia at the time of initial evaluation (median serum creatinine concentration, 2 mg/dL; range, 0.6 to 14.0 mg/dL) and median IRIS stage at that time was 1.5 (range, 0 to 4). At the 3-month post-
operative recheck examination, median creatinine concentration had improved to 1.3 mg/dL (range, 0.3 to 15.9 mg/dL) and median IRIS stage had improved to 0 (range, 0 to 4). Of all the preoperative variables that were evaluated, only preoperative creatinine concentration, BUN concentration, and IRIS stage were associated with long-term outcome, with a hazard ratio for preoperative creatinine concentration of 1.36 (95% confidence interval, 1.167 to 1.594).

An overall median survival time was not reached in the present study, as 30 of 44 (68%) dogs were still alive at the time of last follow-up. Median follow-up time was 1,158 days (range, 3 to >1,555 days), and only 6 of 43 (14%) dogs ultimately died of suspected or confirmed progression of chronic kidney disease. None of the dogs died of recurrent ureteral obstruction, suggesting a good prognosis for dogs with ureteral obstruction.

Other long-term complications such as suspected ureteritis, encrustation of the stent, a minor body wall hernia, and hematuria did not require further surgical intervention. Unlike cats, in which a dysuria rate of 37.7% was reported (although signs only persisted in 1.7% after medical intervention), none of the dogs in the present study reportedly had dysuria following stent placement. We suspect that the reason for this was the intravesicular location of the ureteral stent, compared with the proximal urethral location in cats. Further, whereas 17% of cats with benign ureteral obstructions treated with stenting developed congestive heart failure, this was not noted in the present study population of dogs.

The present study had several limitations. Most importantly, because this was a retrospective study, diagnostic testing and procedures could not be standardized. However, the fact that the same clinicians performed all of the procedures in each dog and were involved in the management of each case over the short and long term meant that there was greater standardization than is typical with most retrospective studies. The cause of death was also uncertain in some cases, as follow-up information often depended on the primary veterinarian’s records or owner’s recollection for patients in which a necropsy was not performed. Sample size precluded multivariate data analysis. Training and extensive experience in minimally invasive procedures and surgical stent placement methods are likely necessary for a successful outcome. The present series of cases were treated at a single institution by a team of clinicians and support staff with extensive experience in these procedures in both dogs and cats.

In conclusion, ureteral stenting appeared to be a safe and effective short- and long-term treatment option for dogs with benign ureteral obstructions. Perioperative complication and mortality rates were lower than those reported with traditional ureteral surgery in dogs and cats. Complications were typically minor, but occasionally necessitated stent exchange or use of an alternative device.

Acknowledgments

Presented in part at the 2014 American College of Veterinary Surgeons Surgery Summit, San Diego; the 2015 American College of Veterinary Internal Medicine Forum, Indianapolis, Ind; and the 2015 Veterinary Endoscopy Society Meeting, Rome, Italy.

Footnotes

b. Vet Stent-Ureter canine, variable length, Infiniti Medical LLC, Menlo Park, Calif.
d. Double-pigtailed ureteral stents, Cook Medical, Bloomington, Ind.
e. Rigid endoscope, 1.9, 2.7, or 4 mm, Storz Karl Storz Endoscopy, Culver City, Calif.
g. Weasel Wire 0.018- or 0.035-inch hydrophilic angle-tipped guide wire, Infiniti Medical LLC, Menlo Park, Calif.
h. 3-5F open-ended ureteral catheter, Cook Medical, Bloomington, Ind.
i. Omnipaque, GE Healthcare, Princeton, NJ.
j. Flexible cystoscope, 3.1 mm, Storz Karl Storz Endoscopy, Culver City, Calif.
k. Polyglactin 910, Ethicon, Somerville, NJ.
l. Monocryl, Ethicon, Somerville, NJ.
m. Esophagostomy tube, MILA International, Erlanger, Ky.
n. Subcutaneous ureteral bypass device, Norfolk Veterinary Products, Skokie, Ill.

References

12. McLouglin MA, Bjorling DE. Ureters. In: Slatter D, ed. Text-


From this month’s AJVR

Use of high-field and low-field magnetic resonance imaging to describe the anatomy of the proximal portion of the tarsal region of nonlame horses
Marianna Biggi and Sue J. Dyson

OBJECTIVE
To use high-field and low-field MRI to describe the anatomy of the proximal portion of the tarsal region (proximal tarsal region) of nonlame horses.

SAMPLE
25 cadaveric equine tarsi.

PROCEDURES
The proximal portion of 1 tarsus from each of 25 nonlame horses with no history of tarsal lameness underwent high-field (1.5-T) and low-field (0.27-T) MRI. Resulting images were used to subjectively describe the anatomy of that region and obtain measurements of the collateral ligaments of the tarsocrural joint.

RESULTS
Long and short components of the lateral and medial collateral ligaments of the tarsocrural joint were identified. Various bundles of the short collateral ligaments were difficult to delineate on low-field images. Ligaments typically had low signal intensity in all sequences; however, multiple areas of increased signal intensity were identified at specific locations in most tarsi. This signal intensity was attributed to focal magic angle effect associated with orientation of collagen fibers within the ligaments at those locations. Subchondral bone of the distal aspect of the tibia was uniform in thickness, whereas that of the medial trochlear ridge of the talus was generally thicker than that of the lateral trochlear ridge. In most tarsi, subchondral bone of the talocalcaneal joint decreased in thickness from proximal to distal.

CONCLUSIONS AND CLINICAL RELEVANCE
Results generated in this study can be used as a reference for interpretation of MRI images of the proximal tarsal region in horses. (Am J Vet Res 2018;79:299–310)