Outcome in cats with benign ureteral obstructions treated by means of ureteral stenting versus ureterotomy

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OBJECTIVE
To evaluate the outcome for cats with benign ureteral obstructions treated by means of ureteral stenting and to compare the outcome for these cats with outcome for a historical cohort of cats treated by means of ureterotomy only.

DESIGN
Prospective study with historical cohort.

ANIMALS
62 client-owned cats with benign ureteral obstructions, including 26 cats treated with ureteral stenting and 36 cats previously treated with ureterotomy.

PROCEDURES
Data were recorded prospectively (ureteral stent cases) or collected retrospectively from the medical records (ureterotomy cases), and results were compared.

RESULTS
Cats treated with ureteral stents had significantly greater decreases in BUN and serum creatinine concentrations 1 day after surgery and at hospital discharge, compared with values for cats that underwent ureterotomy. Six cats in the ureteral stent group developed abdominal effusion after surgery, and cats in this group were significantly more likely to develop abdominal effusion when a ureterotomy was performed than when it was not. Cats that developed abdominal effusion after surgery were significantly less likely to survive to hospital discharge. Cats that underwent ureteral stenting were significantly more likely to have resolution of azotemia prior to hospital discharge than were cats that underwent ureterotomy alone.

CONCLUSIONS AND CLINICAL RELEVANCE
Results suggested that cats with benign ureteral obstructions treated with ureteral stenting were more likely to have resolution of azotemia prior to hospital discharge, compared with cats undergoing ureterotomy alone. Results of ureteral stenting were encouraging, but further investigation is warranted. (J Am Vet Med Assoc 2016;249:1292–1300)

URETERAL OBSTRUCTION IN CATS IS UNCOMMON BUT CAN LEAD TO LIFE-THREATENING ACID-BASE AND ELECTROLYTE DISTURBANCES. AFFECTED CATS ARE OFTEN EXAMINED FOR NONSPECIFIC CLINICAL SIGNS, SUCH AS VOMITING, LETHARGY, AND ANOREXIA, AND FREQUENTLY DEVELOP AZOTEMIA. THE ETIOLOGY OF URETERAL OBSTRUCTIONS MAY BE INTRINSIC OR EXTRINSIC; WITH THE FORMER, CALCULI AND SOLIDIFIED BLOOD CLOTS ARE REPORTEDLY COMMON. BOTH MEDICAL AND SURGICAL TREATMENT OPTIONS FOR URETERAL OBSTRUCTIONS IN CATS HAVE BEEN DESCRIBED. MEDICAL MANAGEMENT CAN INCLUDE FLUID DIURESIS AND ADMINISTRATION OF DIURETICS (EG, Mannitol AND Furosemide) AND SMOOTH MUSCLE RELAXANTS (EG, PRAZOSIN), BUT SURGICAL INTERVENTION IS OFTEN NEEDED. HYDRONEPHROSIS AND HYDROURETER ARE COMMON SEQUELAE OF URETERAL OBSTRUCTION; THEREFORE, PROMPT SURGICAL DECOMPRESSION SHOULD BE CONSIDERED TO PRESERVE RENAL FUNCTION. FEW STUDIES HAVE EVALUATED THE OUTCOME FOR CATS UNDERGOING TRADITIONAL SURGICAL TREATMENT OF URETERAL OBSTRUCTION SECONDARY TO CALCULI. URETEROTOMY, URETERAL RESECTION AND ANASTOMOSIS, AND NEOURETEROCYSTOSTOMY HAVE BEEN DESCRIBED AS SURGICAL TREATMENTS FOR URETERAL OBSTRUCTIONS; REPORTED SUCCESS RATES FOR THESE PROTOCOLS VARY. THE POSTOPERATIVE COMPLICATION RATE IN 1 SERIES OF 153 CATS WAS 31%, WITH URINE LEAKAGE AND PERSISTENT URETERAL OBSTRUCTION BEING THE MOST COMMON COMPLICATIONS REPORTED. PERIOPERATIVE MORTALITY RATE IN THAT SERIES WAS 18%. ADDITIONALLY, URETERAL SURGERY IS RELATIVELY TECHNICALLY DEMANDING AND OFTEN REQUIRES THE USE OF SPECIALIZED EQUIPMENT, SUCH AS INTRAOPERATIVE MICROSCOPY.

More recently, interventional procedures such as ureteral stenting and subcutaneous ureteral bypass device placement have been performed, and early results are promising. Ureteral stenting has been

ABBREVIATIONS
BCS Body condition score
used as a sole treatment for ureteral obstruction in cats and has also been performed in combination with ureterotomy. After placement, these stents allow for immediate passage of urine through the stent lumen and, over time, cause passive dilation of the ureter around the stent. This passive dilation may facilitate the passage of urine, crystals, stones, and other debris through the ureter. Typically, after renal decompression, morbidity and mortality rates are highest in the early postoperative period (ie, days to weeks after treatment), and objective comparison of outcome for patients undergoing these newer procedures versus those being treated by means of traditional surgery is lacking. A detailed evaluation of the clinical course during the postoperative period is warranted, so that clinicians can more effectively guide owners when making the decision to pursue surgery. In addition, with the advent of new treatment modalities, such as ureteral stenting, it is necessary to critically evaluate outcomes. As such, the purposes of the study reported here were to prospectively evaluate the perioperative clinical progression and outcome for a series of cats with benign ureteral obstructions undergoing ureteral stenting and to compare the outcomes between these cats and a historical cohort of cats treated by means of ureterotomy only.

Materials and Methods

Case selection criteria and data collection

Cats undergoing ureteral stenting via an open, normograde approach at the University of California-Davis Veterinary Medical Teaching Hospital between 2010 and 2014 for treatment of benign ureteral obstructions were prospectively enrolled in the study. During this period, ureteral stenting was the preferred treatment option for cats requiring renal pelvic decompression at our hospital. The clinical diagnosis of ureteral obstruction was made by means of ultrasonographic documentation of hydrenephrosis and hydrourereter. Obstruction was confirmed via nephropyelography at the time of the stenting procedure. All ureteral stenting procedures were performed by or under the supervision of the same surgeon (WTNC). The study was approved by the Clinical Trials Review Board of the University of California-Davis, and written informed owner consent was obtained for all enrolled patients. A historical cohort of cats with benign ureteral obstructions treated by means of ureterotomy was identified for comparison. The medical records of cats undergoing ureterotomy at the same hospital between 2003 and 2009 (the time when ureterotomy was more commonly performed) were reviewed. Cats were excluded if medical records were unavailable or incomplete or if the type of surgery could not be ascertained.

Data recorded prospectively (ureteral stent cases) or retrieved from the medical records (ureterotomy-only cases) included history, signalment, clinical signs, results of physical examination, results of laboratory testing, results of diagnostic imaging (when available), details of surgical technique, postoperative complications (if applicable), duration of hospitalization, and outcome. The perioperative period was defined as the time from admission to the hospital for treatment of ureteral obstruction until the time of discharge or euthanasia (during the same visit).

Surgical technique for ureteral stenting

All cats were placed under general anesthesia; the clinical anesthesia service, overseen by board-certified anesthesiologists, determined the anesthetic protocol for all cases. Patients were positioned in dorsal recumbency, and the ventral aspect of the abdomen and perineal region were clipped and prepared for surgery according to standard aseptic technique. A ventral midline laparotomy approach was performed, and Balfour retractors were placed in the cranial aspect of the incision to maintain retraction. An initial exploration of the abdomen was performed. A stay suture of 3-0 or 4-0 polydioxanone was then placed in the apex of the bladder. The affected kidney was grasped (in cats with abundant perirenal fat, careful dissection was first performed), and a 22-gauge over-the-needle catheter was inserted into the greater curvature of the kidney (equidistant dorsoventrally) and advanced into the renal pelvis. When a flash of urine was observed in the over-the-needle catheter, the needle was removed, leaving the catheter in the renal pelvis. A T-port primed with a 1:1 dilution of saline (0.9% NaCl) solution with iodinated contrast solution was attached to the catheter, and the renal pelvis was filled during observation with fluoroscopic guidance to confirm the presence of the catheter within the renal pelvis. A 0.018-in hydrophilic guidewire was introduced into the catheter and advanced in a normograde fashion via the ureter into the bladder. A ventral cystotomy (typically 2 to 3 mm in length) was then performed, and the indwelling bladder guidewire was grasped and passed out of the bladder. The catheter was then removed over the guidewire. A 0.034-in dilator was then passed in normograde manner over the guidewire into the renal parenchyma and through the ureter until it had passed through the ureterovesicular junction. The dilator was then removed, and a ureteral stent was passed over the guidewire (with the length of the ureter measured from the renal pelvis to the bladder used to determine the appropriate stent length). The cranial pigtail of the stent was then positioned in the renal pelvis with fluoroscopic guidance. When appropriate stent placement was confirmed, the guidewire was removed in normograde fashion from the stent, allowing the caudal pigtail of the stent to remain in the bladder. The bladder incision was closed in a simple interrupted pattern with 3-0 or 4-0 polydioxanone. A 3.5F red rubber urinary bladder catheter was placed and secured to the skin. The abdomen was closed in standard fashion.
When passage of a guidewire beyond a ureterolith could not be accomplished, a ureterotomy or ureterotomies were performed to allow the guidewire to bypass the obstruction. To perform the ureterotomies, the section of ureter that contained the stone was dissected free from surrounding tissue. A longitudinal incision was made on the ventral aspect of the ureter with a scalpel, and the ureterolith was exteriorized and removed. The ureterotomy site was closed with 7-0 polydioxanone in a simple interrupted pattern. In all patients that underwent ureterotomy, a closed suction drain was placed. Anesthesia (induction to extubation) and procedure (initial skin incision to final suture placement) times were recorded for all cases.

Surgical technique for ureterotomy
All cats were placed under general anesthesia; the clinical anesthesia service determined the anesthetic protocol for all cases. Cats were positioned in dorsal recumbency, and the ventral aspect of the abdomen and perineal region were clipped and prepared for surgery with standard aseptic technique. A ventral midline laparotomy was performed, Balfour retractors were placed in the cranial aspect of the incision for retraction, and the abdomen was explored. For ureterotomy, the section of ureter that contained the ureterolith was dissected free from surrounding tissue. A longitudinal incision was made on the ventral aspect of the ureter, and the ureterolith was exteriorized and removed. Suture material or a red rubber catheter was then passed into the ureter to confirm patency. After removal of the suture or catheter, the ureterotomy site was closed with suture of various types (polydioxanone, polyglactin, and nylon) and sizes (6-0 to 8-0) in a simple interrupted pattern. The abdomen was closed routinely. Anesthesia (induction to extubation) and procedure (initial skin incision to final suture placement) times were recorded for all cases.

Complications
All complications were categorized as procedural (occurring only during surgery) or postoperative (occurring after surgery until the time of hospital discharge). Additionally, the requirement for ureterotomy in cats undergoing ureteral stenting was considered a procedural complication. Postobstruction diuresis was defined as urine output > 2 mL/kg/h (0.9 mL/lb/h).14

Statistical analysis
The postoperative time period was defined as the time following recovery from anesthesia to hospital discharge. The following variables were compared between groups: age, preoperative clinical signs, duration of preoperative clinical signs, physical examination findings, preoperative clinical laboratory findings, and surgical procedure findings. The change in serum creatinine and BUN concentrations 1 day after stenting versus 1 day after ureterotomy was evaluated by comparing serum creatinine and BUN concentrations before stenting and before ureterotomy with the 1-day postoperative concentrations. Additionally, the percentage change was calculated for these values. Blood urea nitrogen and serum creatinine concentrations before stenting and before ureterotomy were also compared with values obtained at the time of discharge.

Continuous variables (eg, age, clinical laboratory results, duration of clinical signs, and physical examination findings) were assessed for normality with the Shapiro-Wilk test. Normally distributed variables are reported as mean ± SD, and nonnormally distributed variables are reported as the median (range). Normally distributed variables were compared between groups (stenting vs ureterotomy) with a t test, and nonnormally distributed variables were compared between groups with the Mann-Whitney U test. Variables were compared within groups by means of a paired t test or the Wilcoxon signed rank test. Categorical variables (eg, clinical signs and surgical procedure findings) are reported as proportions and percentages; categorical variables were compared between groups by means of the χ2 or Fisher exact test (if any expected cell count was < 5). A value of P ≤ 0.05 was considered significant. All statistical analyses were performed with a statistical software program.1

Results
Ureteral stenting group
Twenty-six cats were enrolled. Mean ± SD age was 9.5 ± 3 years, median weight was 5 kg (11 lb); range, 3.4 to 6.6 kg (7.5 to 14.5 lb), and there were 19 neutered males and 7 spayed females. There were 20 domestic shorthair cats, 2 domestic medium-hair cats, 2 domestic longhair cats, 1 Oicat, and 1 Siamese. Initial clinical signs were summarized (Table 1).

| Table 1—Clinical signs at the time of hospital admission for cats with benign ureteral obstructions treated with ureteral stenting (n = 26) versus ureterotomy only (36). |

<table>
<thead>
<tr>
<th>Clinical sign</th>
<th>Ureteral stenting</th>
<th>Ureterotomy only</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anorexia</td>
<td>19 (73)</td>
<td>22 (61)</td>
<td>0.288</td>
</tr>
<tr>
<td>Lethargy</td>
<td>18 (69)</td>
<td>21 (58)</td>
<td>0.130</td>
</tr>
<tr>
<td>Vomiting</td>
<td>18 (69)</td>
<td>18 (50)</td>
<td>0.510</td>
</tr>
<tr>
<td>Polydipsia</td>
<td>3 (12)</td>
<td>9 (25)</td>
<td>0.168</td>
</tr>
<tr>
<td>Polyuria</td>
<td>0 (0)</td>
<td>7 (19)</td>
<td>0.016</td>
</tr>
<tr>
<td>Pollakuria</td>
<td>2 (8)</td>
<td>1 (3)</td>
<td>0.567</td>
</tr>
<tr>
<td>Signs of abdominal pain</td>
<td>2 (8)</td>
<td>13 (36)</td>
<td>0.010</td>
</tr>
<tr>
<td>Hematuria</td>
<td>1 (4)</td>
<td>2 (6)</td>
<td>1.000</td>
</tr>
<tr>
<td>Stranguria</td>
<td>1 (4)</td>
<td>1 (3)</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Cats treated with ureteral stenting between 2010 and 2014 were prospectively enrolled; cats treated with ureterotomy only were a historical cohort obtained by retrospective review of medical records for cats examined between 2003 and 2009.

*P values represent results of χ2 tests comparing the variables for the 2 groups.
Mean values for heart rate, respiratory rate, and rectal temperature were within reference limits. Clinical signs related to the urinary tract were first noted by owners a median of 3 months (range, 1 to 59 months) prior to initial evaluation, whereas the median time from when cats were last healthy (as defined by the owner) to initial examination was 15.5 days (range, 1 to 96 days). Sixteen cats were euhydrated, 6 were underhydrated, and 4 were overhydrated on the basis of physical examination results at the time of initial evaluation. On the basis of BCS, 9 cats were considered underweight (BCS < 5 on a scale of 1 to 9), 7 were considered to be an appropriate weight (BCS = 5), and 10 were considered to be overweight (BCS > 5). A heart murmur was evident on thoracic auscultation in 8 of the 26 (31%) cats. Signs of abdominal pain were noted during abdominal palpation in 11 cats (42%), and 12 cats (46%) had large kidneys on palpation or specific signs of pain on palpation of the kidneys.

Laboratory testing performed at the time of initial evaluation included a CBC and serum biochemical profile (Table 2). Anemia was noted in 73% (19/26) of cats; 31% (8/26) were hypoproteinemic, and 4% (1/26) were hyperproteinemic. High serum creatinine and BUN concentrations were identified in 92% (24/26) and 85% (22/26) of cats, respectively. Forty-two percent (11/26) of cats were hyperkalemic, and 8% (2/26) were hypokalemic. Urine specific gravity was measured in 21 cats; 7 were hypersthenuric (urine specific gravity > 1.008), 9 were isosthenuric (urine specific gravity, 1.008 to 1.012), and 5 were hyposthenuric (urine specific gravity < 1.008). Urine samples from 23 cats were submitted for bacterial culture and susceptibility testing. Results of bacterial culture were positive for 2 cats (Escherichia coli), although 8 cats had received antimicrobials prior to admission. Both E coli isolates were susceptible to amikacin, gentamicin, amoxicillin-clavulanic acid, enrofloxacin, marbofloxacin, and imipenem.

Preoperative abdominal radiographs were obtained in 18 of the 26 (69%) cats. Unilateral kidney enlargement was seen in 8 of the 18 cats, and a unilateral decrease in kidney size was seen in another 8. Nephroliths were noted in 10 of the 26 (38%) cats, with 3 cats having bilateral nephroliths. Six of the 26 (23%) cats had radiographically evident ureteroliths, with 1 cat suspected of having > 2 ureteroliths visible on radiographs. Two (8%) cats had cystoliths. Ureteral dilation was suspected in 3 of the 26 (12%) cats on the basis of results of radiography.

All 26 cats underwent preoperative abdominal ultrasonography. Abnormalities included bilateral hydronephrosis and ureteral dilation (8/26 [31%]), bilateral hydronephrosis with unilateral ureteral dilation (2/26 [8%]), bilateral hydronephrosis with no ureteral dilation (1/26 [4%]), right-sided hydronephrosis and ureteral dilation (10/26 [38%]), and left-sided hydronephrosis and ureteral dilation (5/26 [19%]). Ureteral calculi were visualized or suspected on the basis of shadowing or a hyperechoic structure in the ureter in 13 of the 26 (50%) cats.

Median time from hospital admission to surgery was 44 hours (range, 5 to 201 hours). A total of 35 ureteral stents were placed in the 26 cats (7 bilateral and 19 unilateral), with 19 right-sided ureteral stents and 14 left-sided ureteral stents. The size and length of the stents placed were 2F X 10 cm, 2.5F X 12 cm, and 2.5F X 14 cm in 4, 28, and 1 cat ureters, respectively. An active abdominal drain was placed in 10 of the 26 (38%) cats and remained in place a median of 4 days (range, 1 to 8 days). Median procedure time was 193 minutes (range, 30 to 310 minutes), and median anesthesia time was 325 minutes (range, 240 to 530 minutes). An esophagostomy tube was placed in all 26 cats.

Procedural complications included the need for at least 1 ureterotomy in 5 of the 26 (19%) cats. A total of 7 ureterotomies were performed to allow for guidewire passage (2 cats with 2 ureterotomies each and 3 cats with 1 ureterotomy each) when the guidewire would not pass a ureterolith or ureteroliths. One cat required 5 pyelocentesis attempts to appropriately position the over-the-needle catheter within the renal pelvis. In another cat, the stent was noted with fluoroscopy to be easily migrating out of the renal pelvis during the procedure, and a suture was passed through the proximal pigtail to allow the pigtail to be positioned within the pelvis; the suture was passed through the nephrocentesis site with both ends exiting the kidney capsule, allowing it to be sutured to the capsule.

Major postoperative complications included post-obstructive diuresis (n = 26), anemia (26), and ab-

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of cats</th>
<th>Value*</th>
<th>Reference range</th>
<th>P value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCV (%)</td>
<td>26</td>
<td>30 ± 7</td>
<td>30–35</td>
<td>0.492</td>
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<tr>
<td>Total protein (g/dL)</td>
<td>26</td>
<td>6.5 ± 0.9</td>
<td>5.4–6.9</td>
<td>0.129</td>
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<tr>
<td>Potassium (mmol/L)</td>
<td>26</td>
<td>5.1 ± 1.3</td>
<td>3.6–4.8</td>
<td>0.777</td>
</tr>
<tr>
<td>Creatinine (mg/dL)</td>
<td>26</td>
<td>8.4 (1.6–20.5)</td>
<td>1.1–2.2</td>
<td>0.635</td>
</tr>
<tr>
<td>BUN (mg/dL)</td>
<td>26</td>
<td>129 (27–308)</td>
<td>18–33</td>
<td>0.833</td>
</tr>
</tbody>
</table>

*Data are given as mean ± SD or median (range). †The P values represent results of a t test (normally distributed variables) or the Mann-Whitney U test (non-normally distributed variables) comparing variables for the 2 groups.

Table 2—Results of serum biochemical analyses performed at the time of hospital admission for cats in Table 1.
dominal effusion (6). All 26 cats had postobstructive diuresis with a median maximum urine output of 7.75 mL/kg/h (3.5 mL/lb/h; range, 3 to 36.5 mL/kg/h [1.4 to 16.6 mL/lb/h]). All 26 cats were anemic at some time after surgery (median PCV, 16%; range, 13% to 28%). Five of the 6 cats that developed postoperative abdominal effusion had uroabdomen; the type of effusion in the remaining cat was not determined. Of the 5 cats with a postoperative uroabdomen, 4 had undergone ureterotomy; in the cat that did not undergo ureterotomy, the cause of the urine leakage was not known, although it could have been secondary to undetected iatrogenic intraoperative ureteral puncture, a small ureteral tear, or cystotomy incisional leakage. An abdominal drain had been placed during surgery in all 6 cats, and the effusion resolved within 3 days in all cats without any further treatment.

Follow-up abdominal ultrasonography was performed in the early postoperative period in 23 of the 26 cats. Improvements in the severity of hydronephrosis and ureteral dilation were noted in 19 of 23 and 18 of 23 cats, respectively. Worsening hydronephrosis and ureteral dilation were evident in 1 cat each, and no change was noted in the hydronephrosis and ureteral dilation in 3 and 4 cats, respectively.

Median serum creatinine and BUN concentrations prior to ureteral stent placement were 8.4 mg/dL (range, 1.6 to 20.5 mg/dL) and 129 mg/dL (range, 27 to 308 mg/dL), respectively. A serum biochemical profile was repeated 1 day after surgery and at the time of hospital discharge (Table 3). One day after stenting, 96% (25/26) and 81% (21/26) of cats had a decrease in serum creatinine and BUN concentrations, respectively. Mean ± SD serum potassium concentration 1 day after stenting was 4.2 ± 0.7 mmol/L; 13% (3/24) of cats were hyperkalemic, and 17% (4/24) were hypokalemic.

Of the 26 cats, 24 (92%) were discharged. One cat developed acute respiratory distress and died 11 days after surgery despite improvements in serum creatinine and BUN concentrations. The other cat was euthanized after several days of worsening azotemia despite an initial improvement in renal parameters within the first 24 hours after surgery. On the day of discharge, 38% (9/24) of cats had a serum creatinine concentration higher than the upper reference limit, and 33% (8/24) of cats had a BUN concentration higher than the upper reference limit. Mean serum potassium concentration at the time of hospital discharge was 4.5 ± 1 mmol/L; 17% (4/24) of cats were hyperkalemic, and 8% (2/24) were hypokalemic. At discharge, 96% (23/24) and 92% (22/24) of cats, respectively, had serum creatinine and BUN concentrations lower than values recorded at the time of initial examination. At the time of discharge or death, azotemia (defined as a high serum creatinine concentration, high BUN concentration, or both) had resolved in 16 of 26 (62%) cats; median time to resolution of azotemia after surgery was 2 days (range, 1 to 5 days). Median total hospitalization time was 7.5 days (range, 4 to 17 days), and median hospitalization time after surgery was 5 days (range, 2 to 15 days).

**Ureterotomy group**

Thirty-six cats were enrolled; complete medical records data were not available for all variables. Mean ± SD age was 8.6 ± 3 years, median weight was 4.5 kg (10 lb; range, 3 to 8 kg [6.6 to 17.6 lb]), and there were 14 castrated males and 22 spayed females. There were 22 domestic shorthair cats, 4 domestic longhair cats, 2 domestic medium-hair cats, 3 Siamese, 2 Himalayans, 1 Japanese Bobtail, 1 Maine Coon, and 1 Manx. Initial clinical signs were summarized (Table 1). In all cats, mean values for heart rate, respiratory rate, and rectal temperature were within reference limits. Clinical signs related to the urinary tract were first noted by owners a median of 3 months (range, 1 to 50 months) prior to initial evaluation, whereas the median time from when cats were last healthy (as defined by the owner) to initial examination was 4 days (range, 1

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**Table 3**—Results of serum biochemical analyses performed 1 day after ureteral stenting or ureterotomy and at the time of hospital discharge for cats in Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ureteral stenting</th>
<th>Ureterotomy only</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Median (range)</td>
<td>No.</td>
</tr>
<tr>
<td><strong>1 day after surgery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creatinine (mg/dL)</td>
<td>26</td>
<td>4.2 (1.1 to 17.7)</td>
<td>28</td>
</tr>
<tr>
<td>Change in creatinine (mg/dL)</td>
<td>26</td>
<td>–2 (–15.6 to 2.5)</td>
<td>28</td>
</tr>
<tr>
<td>Change in creatinine (%)</td>
<td>26</td>
<td>–33 (–73 to 116)</td>
<td>28</td>
</tr>
<tr>
<td>BUN (mg/dL)</td>
<td>26</td>
<td>70 (19 to 294)</td>
<td>28</td>
</tr>
<tr>
<td>Change in BUN (mg/dL)</td>
<td>26</td>
<td>–15 (–186 to 5)</td>
<td>28</td>
</tr>
<tr>
<td>Change in BUN (%)</td>
<td>26</td>
<td>–18 (–61 to 87)</td>
<td>28</td>
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<table>
<thead>
<tr>
<th>At time of discharge</th>
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<tbody>
<tr>
<td>Creatinine (mg/dL)</td>
<td>24</td>
<td>2.2 (1.1 to 7.9)</td>
<td>27</td>
<td>2.6 (1.2 to 8.5)</td>
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<tr>
<td>Change in creatinine (mg/dL)</td>
<td>24</td>
<td>–6.5 (–18.7 to 0.3)</td>
<td>27</td>
<td>–1.6 (–23.2 to 18)</td>
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<tr>
<td>Change in creatinine (%)</td>
<td>24</td>
<td>–68 (–94 to 19)</td>
<td>27</td>
<td>–29 (–93 to 97)</td>
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<tr>
<td>BUN (mg/dL)</td>
<td>24</td>
<td>32 (19 to 294)</td>
<td>27</td>
<td>42 (14 to 150)</td>
</tr>
<tr>
<td>Change in BUN (mg/dL)</td>
<td>24</td>
<td>–71.5 (–272 to 6)</td>
<td>27</td>
<td>–9 (–296 to 54)</td>
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<tr>
<td>Change in BUN (%)</td>
<td>24</td>
<td>–57 (–94 to 8)</td>
<td>27</td>
<td>–21 (–95 to 121)</td>
</tr>
</tbody>
</table>

*The P values represent results of the Mann Whitney U test comparing variables for the 2 groups.*
isolates (31%) cats, and 13 (36%) cats had large ureteroliths. An active abdominal drain was placed in 1 cat and remained in place for 3 days. Median procedure time was 125 minutes (range, 52 to 385 minutes), and median anesthesia time was 243 minutes (range, 130 to 765 minutes). An esophagostomy tube was placed in 18 of 36 (50%) cats.

Procedural complications included blood loss requiring packed RBC transfusion in 2 of 36 (6%) cats, an accidental ureteral puncture in 1 (3%) cat, and cardiopulmonary arrest in 1 (3%) cat that was resuscitated. Additionally, in 3 (8%) cats, ureteroliths were seen in the ureter during an ultrasonographic examination after surgery; a second surgery was performed in 1 of these cats.

Similar to the ureteral stenting group, the most common major postoperative complications were postobstructive diuresis, anemia, and abdominal effusion. Eighteen of 21 cats had postobstructive diuresis (median urine output, 5.3 mL/kg/h [2.4 mL/lb/h]; range, 0.3 to 40 mL/kg/h [0.14 to 18.2 mL/lb/h]). Ninety-seven percent (35/36) of cats were anemic at some time after surgery, prior to discharge (median PCV, 20%; range, 11% to 34%). Eleven of 12 cats that developed abdominal effusion after surgery had uroabdomen; the type of effusion in the remaining cat was not determined. Additionally, 4 cats were presumed to be iatrogenically overhydrated on the basis of the presence of pleural effusion, 2 cats developed seizures, and 2 cats each were deemed to be oliguric or anuric after surgery.

Follow-up abdominal ultrasonography was performed during the postoperative period in 18 of 36 cats. Improvements in the severity of hydronephrosis and ureteral dilation were noted in 13 of 18 and 10 of 18 cats, respectively. Worsening hydronephrosis and ureteral dilation were evident in 2 and 1 cats, respectively, and no change was noted in the hydronephrosis and ureteral dilation when compared with preoperative images in 3 and 7 cats, respectively. A single ureterolith was still present in 2 cats, and 1 cat had multiple ureteroliths remaining.

Median serum creatinine and BUN concentrations prior to ureterotomy were 6.7 mg/dL (range, 1.3 to 26 mg/dL) and 89 mg/dL (18 to 33 mg/dL), respectively. Not all laboratory values were available for all 36 cats 1 day after ureterotomy or at the time of hospital discharge. The day after surgery, 13 of 28 (46%) and 8 of 28 (29%) cats for which data were available had a decrease in serum creatinine and BUN concentrations, respectively. Mean ± SD serum potassium concentration 1 day after surgery was 4.4 ± 0.77 mmol/L; 8 of 32 (25%) cats were hyperkalemic, and 4 of 32 (13%) were hypokalemic.

Of the 36 cats, 28 (78%) were discharged. Results of clinical laboratory testing performed on the day of discharge were available for 27 of the 28 cats; 16 (59%) had a serum creatinine concentration higher than the upper reference limit, and 16 (59%) had a BUN concentration higher than the upper reference limit. Mean serum potassium concentration at the time of hospital discharge was 4.5 ± 0.88 mmol/L; 6 of 27 (22%) cats were hyperkalemic, and none were hypokalemic. At discharge, 20 of 27 (74%) cats and 21 of 27 (78%) cats, respectively, had serum creatinine concentrations than the upper reference limit, and 16 (59%) had a BUN concentration higher than the upper reference limit. Mean serum potassium concentration at the time of hospital discharge was 4.5 ± 0.88 mmol/L; 6 of 27 (22%) cats were hyperkalemic, and none were hypokalemic. At discharge, 20 of 27 (74%) cats and 21 of 27 (78%) cats, respectively, had serum creatinin...
nine and BUN concentrations lower than values recorded at the time of initial examination. At the time of discharge or death, azotemia had resolved in 11 of 36 (31%) cats; median time to resolution of azotemia after surgery was 2 days (range, 1 to 8 days). Median hospitalization time was 8.5 days (range, 2 to 32 days), and median hospitalization time after surgery was 4.5 days (range, 1 to 11 days).

Statistical analyses
Survival to discharge was not significantly associated with patient age or with initial body weight, rectal temperature, respiratory rate, or heart rate. In addition, neither results of initial laboratory testing nor the time between initial examination and the last time the cat was reported to be healthy was significantly associated with the likelihood of discharge from the hospital. Cats that developed abdominal effusion after surgery were significantly ($P = 0.003$) less likely to be discharged from the hospital, and cats with resolution of azotemia during hospitalization were significantly ($P = 0.003$) more likely to be discharged from the hospital.

There were no significant differences between groups (ureteral stenting vs ureterotomy only) with regard to age, weight, or sex distribution. When comparing cats that underwent ureteral stenting with cats that underwent ureterotomy without stenting, an abdominal drain ($P < 0.001$) and an esophagostomy tube ($P < 0.001$) were significantly more likely to be placed in cats undergoing stenting then in cats undergoing ureterotomy alone. There was no significant difference between groups with regard to severity of postoperative anemia ($P = 0.159$), but cats undergoing ureteral stenting were significantly ($P < 0.001$) more likely to develop postobstructive diuresis than were cats undergoing ureterotomy alone. Cats with greater postobstructive diuresis were significantly ($P = 0.029$) more likely to be discharged.

Cats in the ureteral stenting group were significantly ($P = 0.005$) more likely to develop postoperative abdominal effusion when a ureterotomy was also performed than when it was not. However, there was no significant ($P = 0.171$) difference in the proportion that survived to discharge between these 2 groups.

When comparing the ureteral stenting and ureterotomy groups, there was no significant ($P = 0.590$) difference in the time to postoperative improvement in azotemia, although cats in the stenting group were significantly ($P = 0.015$) more likely to have resolution of azotemia prior to discharge. Additionally, there was no significant difference between groups with regard to hospitalization time ($P = 0.883$) or likelihood of developing uroabdomen ($P = 0.515$).

Discussion
Results of the present study, in which outcome for cats with benign ureteral obstructions treated by means of ureteral stenting over a 5-year period (2010 through 2014) was compared with outcome for a historical cohort of cats treated with ureterotomy alone between 2003 and 2009, suggested that use of ureteral stents can be successful. Greater early postoperative improvement in clinical laboratory indices of renal function was found in cats that underwent ureteral stenting, compared with results for cats that underwent ureterotomy alone. Additionally, whereas complications were encountered, 24 of 26 cats that underwent ureteral stenting survived to discharge.

Historically, benign obstructions of the ureter in cats have presented a therapeutic challenge because of their anatomic location, the small size of the ureter in cats, and the relative technical difficulties of available surgical procedures. However, over the past several years, newer techniques integrating interventional radiologic guidance and specialized equipment have shown promising outcomes. The addition of cases to the growing research evaluating these techniques and comparison of various treatment strategies are important. Cats undergoing ureteral stenting in the present study demonstrated marked improvement in laboratory values in the immediate postoperative period. When comparing the initial median creatinine concentration with the median creatinine concentration at discharge, a substantial decrease from 8.4 mg/dL (range, 1.6 to 20.5 mg/dL) to 2.2 mg/dL (range, 1.1 to 7.9 mg/dL) was noted. All but one (25/26) of the cats in the ureteral stenting group had a decrease in creatinine concentration, and 81% (21/26) had a decrease in BUN concentration 1 day after the procedure. Additionally, the ureteral stenting group had significantly greater decreases in BUN and creatinine concentrations, compared with decreases for the ureterotomy-only group. By the time of discharge, 96% (23/24) and 92% (22/24) of cats that underwent ureteral stenting had serum creatinine and BUN concentrations lower than values recorded at the time of initial examination. Perhaps more importantly, azotemia resolved in 62% (16/26) of cats in the ureteral stent group, compared with 31% (11/36) of cats in the ureterotomy-only group. Whereas long-term outcome after discharge for cats in the present study was not evaluated, a previous study reported that high creatinine concentration at the time of discharge was associated with a shorter survival time.

We believe that results of the present study were encouraging. Because the initial goal of ureteral stent placement was to provide renal decompression by allowing urine passage, the early decrease in azotemia supported the success of this procedure. Furthermore, in most cats (16/26 [62%]) undergoing ureteral stenting in this study, azotemia resolved during the early postoperative period when cats were in the hospital, and this was significantly more likely to occur in cats undergoing stenting, compared with cats treated with ureterotomy alone. Lastly, survival to discharge was 92% (24/26) for the ureteral stenting group versus 78% (28/36) for the ureterotomy-only group.
In the present study, the significant improvement in clinical laboratory values for cats in the ureteral stent group versus the ureterotomy group could have been secondary to improved urine passage through the stent. Possibly, cats in the ureterotomy-only group may have experienced some persistent ureteral obstruction secondary to preexisting ureteral stricture (eg, from ureterolith irritation), inflammation associated with the ureterotomy incision and closure, or a suture reaction. Cats undergoing ureteral stenting in the present study were significantly ($P < 0.001$), more likely to develop postobstructive diuresis, which might be associated with more successful relief of obstruction in those patients. Additionally, more cats in the ureterotomy group developed postoperative uroabdomen, and this likely contributed to the finding that fewer cats in that group showed improvement in azotemia.

The use of ureteral stenting in companion animals was first described by Berent et al in 2007, and currently, there are a few studies evaluating ureteral stenting in veterinary patients. To date, the largest study reviewing ureteral stenting in cats described outcomes in 69 cats. In those cats, stent placement was successful in most cases (95%) and the complication rate was low. Overall, the procedure was considered effective and the prognosis good when performed by experienced clinicians. In cats, ureteral stents are generally placed after laparotomy. Access to the ureter can be obtained in either a normograde (through the kidney) or retrograde (from the ureteral orifice) direction. We prefer a normograde approach, as this allows for the guidewire to be grasped on both the kidney and bladder side. In our experience, this control of the guidewire improves the ability to effectively pass the ureteral dilator and stent. Even with this technique, it was still necessary to perform 7 ureterotomies in 5 cats (the most common intra-procedural complication) in the ureteral stenting group in the present study to allow the guidewire to pass the obstructed region. A previous study that evaluated the use of ureterotomy to treat benign ureteral obstructions in 153 cats noted that 5 cats undergoing ureterotomy had a persistent ureteral obstruction. Although not evaluated in the present study, 1 goal of ureteral stent placement is to prevent this complication from occurring in cats undergoing ureterotomy.

In the present study, the procedure and anesthesia times in both groups were relatively long (a median of 193 minutes and 325 minutes, respectively). In the present study, urinary catheters, jugular catheters, and esophageal feeding tubes were placed, which prolonged the anesthesia times. Additionally, postoperative radiography of the esophageal tube and stent were performed to confirm appropriate positioning. Prolonged duration of anesthesia in cats with preexisting kidney disease is obviously not ideal, and future evaluation of the importance of these interventions is necessary to allow for anesthesia time to be minimized as much as possible.

The major postoperative complications of anemia and postobstructive diuresis associated with ureteral stenting in the cats of the present study were successfully treated with diligent postoperative monitoring and early intervention. Anemia is a common complication in cats with benign ureteral obstructions. Whereas many cats of this study developed severe anemia during hospitalization, this was not associated with decreased survival to discharge, and there was no significant difference in the severity of the anemia between the 2 study groups.

The development of diuresis after relief of a urinary tract obstruction is a well-documented phenomenon in human patients. All of the cats undergoing ureteral stenting in the present study developed postobstructive diuresis, and this likely contributed to the prolonged postoperative hospitalization time (median, 5 days; range, 2 to 15 days). Furthermore, all cats in the ureteral stent group had esophagostomy tubes placed, in part, to allow for water administration to maintain hydration and also in an effort to decrease blood volume expansion, as can occur with IV administration of sodium-containing crystalloid fluids. A major focus in the management of cats treated for ureteral obstruction is maintaining blood volume and hydration status while preventing fluid overload postoperatively. Overhydration has been reported to negatively impact survival to discharge in cats undergoing renal decompression by means of interventional-guided procedures. Cats undergoing ureteral stenting were significantly more likely to develop postobstructive diuresis in the present study, and cats with a larger volume of postobstructive diuresis were significantly more likely to be discharged.

Postoperative development of abdominal effusion significantly decreased the likelihood of survival to discharge among cats in the present study. Uroabdomen was diagnosed in 4 of 5 cats that underwent ureteral stenting and also required a ureterotomy. We prefer to pass the guidewire and stent past a ureteral obstructive lesion, rather than performing a ureterotomy, in an effort to decrease the risks for development of postoperative uroabdomen or ureteral stricture. The likelihood for developing postoperative abdominal effusion significantly increased when a ureterotomy was performed in conjunction with ureteral stent placement in the cats of the present report.

There were several limitations of the present study. The cats included in the 2 groups were treated at different times at our clinic, and advancements in the quality of available diagnostic and treatment modalities for the management of cats with ureteral obstructions may have influenced outcome data. Furthermore, follow-up evaluation of these cats was limited to the immediate postoperative period, and complications related to the procedures may have been encountered over the long term. Cats undergoing ureterotomy only were treated by various surgeons, whereas cats undergoing ureteral stenting were treated by a single surgeon or by individuals under the
supervision of that surgeon. Lastly, because this study included retrospective data, inherent issues such as medical record inaccuracies or inconsistencies in the recording of data may have occurred. In particular, abdominal ultrasonography was not performed postoperatively in all cats, and the development of uroabdomen may have been underdiagnosed.

Ureteral stent placement for treatment of benign ureteral obstructions in cats is a relatively new procedure, but early postoperative results in the present study were encouraging. Further evaluation of ureteral stenting and other recently introduced alternatives, such as subcutaneous ureteral bypass, is necessary so that optimal evidence-based treatment plans suited to each individual patient can be developed.

Footnotes

a. Subcutaneous Ureteral Bypass Device, Norfolk Vet Products, Skokie, Ill.
b. PDS, Ethicon Inc, Somerville, NJ.
c. Angiocath, Becton, Dickinson & Co, Franklin Lakes, NJ.
d. Isovue 370, Bracco Diagnostics, Princeton, NJ.
e. Weasel wire, Infiniti Medical, Menlo Park, Calif.
f. Vet Stent, Ethicon Inc, Somerville, NJ.
g. Red rubber catheter, Bard Medical, Murray Hill, NJ.
h. Jackson-Pratt Drain, Cardinal Health, Dublin, Ohio.
i. Vicryl, Ethicon Inc, Somerville, NJ.
j. Ethilon, Ethicon Inc, Somerville, NJ.
k. Stata, version 12.0 for Mac, Stata Corp, College Station, Tex.

References


