

**STANDARD ARTICLE**

# Subcutaneous ureteral bypass device placement in 81 cats with benign ureteral obstruction (2013-2018)

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**Abstract**

**Background:** Benign ureteral obstructions (BUOs) present a therapeutic challenge in cats.

**Hypothesis/Objectives:** The purpose of this study was to determine the outcome and complications associated with placement of subcutaneous ureteral bypass (SUB) device in cats.

**Animals:** Eighty-one client-owned cats (117 kidneys) with BUO treated by placement of a SUB.

**Methods:** Retrospective study. Medical records of cats with BUO and treated by SUB device placement between 2013 and 2018 were reviewed. Outcome and complications were documented.

**Results:** Hospital discharge rate was 94% (76/81). Serum creatinine on admission and at the time of discharge was 5.3 mg/dL (range, 1.2 to >15 mg/dL) and 2.1 mg/dL (range, 1.1-12.5 mg/dL), respectively. Luminal obstructions were documented in 17% (18/109) of the SUB devices of 16 cats discharged from the hospital. Infection was documented in 26% (20/76) of discharged cats. Kink of the device was documented in 10% (12/117) of devices. Time to luminal obstruction and kink were 204 days (range, 21-1678 days) and 58 days (range, 2-601 days), respectively. Fourteen of 81 (17%) cats required a revision surgery in order to restore patency of the device. At the time of writing, 53% (43/81) of cats were alive, with a mean survival time of 821 days (range, 1-2170 days) after surgery. Of those that died, 52% (20/38) died of urinary related causes.

**Conclusion and Clinical Importance:** This study suggests that SUB device placement is associated with good outcomes and could be considered for the treatment of BUO in cats.

**KEYWORDS**

cat, interventional radiology, positional kink, subclinical bacteriuria, ureterolithiasis

**Abbreviations:** BUO, benign ureteral obstruction; CI, confidence interval; CKD, chronic kidney disease; IRIS, International Renal Interest Society; LUTD, lower urinary tract disease; LUTI, lower urinary tract infection; MST, mean survival time; SB, subclinical bacteriuria; SUB, subcutaneous ureteral bypass; tEDTA, tetrasodium EDTA; TPA, tissue plasminogen activator

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## 1 | INTRODUCTION

Benign ureteral obstruction (BUO) occurs in cats and can be secondary to ureterolithiasis, ureteral strictures, infection, dried solidified blood stones, retroperitoneal fibrosis after renal transplant, or iatrogenic ureteral ligation.<sup>1-10</sup> Obstructive calcium oxalate ureterolithiasis is the most frequent cause of BUO in cats.<sup>8-11</sup> Cats with BUO often have chronic kidney disease (CKD) and are azotemic at the time of presentation.<sup>2,3,5,8,9,12-14</sup>

There are various options available for the treatment of BUO. Medical treatment is often ineffective with a decrease in creatinine occurring in 13% of treated cats.<sup>15</sup> Ureteral surgeries are associated with a high rate of postoperative death (8%-22%).<sup>13,15-17</sup> Ureteral stenting is associated with good long-term outcomes and lower case fatality rates (7.5%-9%) compared to traditional surgery but placement can be challenging, and recurrent ureteral obstruction might occur.<sup>12-14,17-19</sup> Intermittent signs of lower urinary tract disease (LUTD) with negative urine culture can occur postoperatively with up to 20% to 54% of the cats presenting some pollakiuria, dysuria, hematuria, and stranguria.<sup>13,17-19</sup> Stent exchange is required in 27% of cats.<sup>18</sup>

Subcutaneous ureteral bypass (SUB) device placement is an effective treatment option for BUO in cats.<sup>6-10,12,14,20</sup> A retrospective study of SUB device placement in 174 ureters of 134 cats demonstrates the advantages of SUB placement as a treatment of BUO in cats compared to other options with a 6% postoperative death rate and fewer long-term complications compared to other surgical options.<sup>8</sup>

The aims of the study were to determine outcome and complications in a large cohort of cats undergoing SUB device placement had BUO at our hospital.

## 2 | MATERIALS AND METHODS

### 2.1 | Retrospective study

Medical records of all cats with BUO that underwent SUB device placement by the authors (C. Vachon or M. Dunn) between April 2013 and December 2018 at the CHUV of Saint-Hyacinthe (Quebec, Canada) were retrospectively reviewed. Results of bloodwork, urinalysis, urine culture performed at the CHUV, preoperative imaging findings, treatments, and short- and long-term complications were recorded.

### 2.2 | Preoperative management

Cats with a heart murmur noted underwent echocardiography. Cats were stabilized before undergoing SUB device placement (24 hours of hospitalization with fluid therapy and correction of electrolyte imbalances) or promptly taken to surgery if they could not be stabilized and were unresponsive to medical treatment. Alpha-receptor antagonist (prazosin hydrochloride [Teva Canada Limited, Whitchurch-Stouffville,

Canada] 0.5 mg total PO q8-12h) was discontinued at least 8 hours before anesthesia induction. Prophylactic perioperative antibiotics were administered (cephazolin [Cefazolin, Teva Canada Limited, Whitchurch-Stouffville, Canada] 22 mg/kg q2h). Pre- and postoperative antibiotics were administered based on results of urine culture and sensitivity.

All cats were blood typed and cross-matched before surgery.

On induction, cats with a serum creatinine >7.9 mg/dL (>700  $\mu$ mol/L) received 1 injection (1  $\mu$ g/kg SC) of desmopressin acetate (DDAVP Rhinyle, Ferring Inc, Toronto, Canada) to reduce platelet associated bleeding secondary to uremia.<sup>21-23</sup>

At surgery, urine from the obstructed kidney was sampled for bacterial culture. Antegrade ureteropyelography using a 50/50 mixture of sterile saline (0.9% NaCl) and iopamidol contrast (Isovue, Bracco Imaging Contrast, Anjou, Canada) was performed to confirm ureteral obstruction and facilitate SUB device placement.

### 2.3 | SUB device placement

A commercial SUB device 1.0 (Norfolk Vet Products, Skokie, Illinois) with straight cystotomy catheter was placed in all cats during the study period. Subcutaneous ureteral bypass device placement was performed as described.<sup>8</sup> Cats with severe azotemia (>7.9 mg/dL, >700  $\mu$ mol/L) and partial/complete anorexia with or without weight loss had an esophagostomy tube placed. A urinary catheter was not placed at the time of surgery to reduce risks of postoperative bacteriuria.<sup>8</sup>

### 2.4 | Postoperative management

Fluid therapy was adapted for each cat based on their hydration status, body weight, urine output, PCV, and total solids. Analgesia was provided postoperatively using continuous rate infusions of remifentanyl (Sandoz Canada, Boucherville, Canada), fentanyl (Sandoz Canada, Boucherville, Canada) or ketamine (Sandoz Canada, Boucherville, Canada) at standard doses and gabapentin (5-10 mg/kg q8h; Summit Veterinary Pharmacy, Aurora, Canada), PO or buprenorphine (sublingually 10 and 15  $\mu$ g/kg q12h-q8h; Summit Veterinary Pharmacy, Aurora, Canada). Antibiotics—amoxicillin/clavulanic acid ([Clavaseptin, Vetoquinol, Lavaltrie, Canada] 15-20 mg/kg q12h PO)—were administered for 7 to 10 days postoperatively. If a positive urine culture was noted, 4 to 6 weeks of antibiotic administration were prescribed.

Creatinine, electrolytes, total solids, and PCV were assessed every 12 to 24 hours until discharge. A urinary tract ultrasound was performed daily to assess pelvic and ureteral dilatation and detect postoperative complications. All cats underwent an ultrasound-guided SUB flush before discharge.

### 2.5 | Follow-up

Postoperative data were collected, 1, 3, 6, 9 and 12 months and every 3 months long term postoperatively until death or the end of the

study period. Upon rechecks, a physical examination, blood pressure, renal profile, PCV, total solids, urine culture, and an ultrasound-guided SUB flush were performed. Cats were classified according to International Renal Interest Society (IRIS) CKD staging guidelines.<sup>24</sup>

## 2.6 | Complications

Complications after SUB device placement were divided into 3 categories; (a) Perioperative complications occurred from the time of surgery to 7 days postoperatively; (b) short-term from 8 to 30 days postoperatively; (c) long-term from 31 days postoperatively until the last available follow-up or the end of the study. For each complication, the time elapsed from surgery, the creatinine at the time of the complication, and whether the cat needed medical treatment or a corrective surgery were recorded.

Recorded complications included among others subclinical bacteriuria (SB), signs of LUTD, lower urinary tract infection (LUTI), and pyelonephritis. Subclinical bacteriuria was defined as a positive urine culture in the absence of clinical signs; signs of LUTD, the presence of pollakiuria, hematuria, or stranguria with a negative urine culture; LUTI, signs of LUTD associated with a positive urine culture. Pyelonephritis was defined as an increase in the serum creatinine concentration, a positive urine culture (urine collection from the SUB device) associated with the presence of systemic clinical signs (hyperthermia, lethargy, decreased appetite, vomiting), with or without signs of LUTD.

In cats that died during the study period, time elapsed from surgery and cause of death were recorded. Cats were then further divided into urinary or nonurinary related deaths.

When an obstruction of the SUB device was suspected during a SUB flush, a fluoroscopic-guided contrast study was performed to rule out a static or partial/positional kink. If an intraluminal obstruction due to mineralization was suspected, 4% tetrasodium EDTA (tEDTA, KiteLock 4% Sterile Catheter lock, Stevens Limited Company, Brampton, Canada) was infused into the SUB device to re-establish patency. Before availability of tEDTA (September 2017), mineralized obstructed tubes were replaced surgically if the cat had evidence of renal pelvis obstruction. Cats with kinks resulting in pelvic dilatation also returned to surgery for correction of the kink.

## 2.7 | Statistical analysis

Survival time was calculated from the surgery date to date of death for those cats that died during the follow-up period. Survival times for cats still alive at the end of the study or that died of a nonurinary related death were considered censored. Overall survival times were obtained with Kaplan-Meier curves. The association between risk factors and cat survival over the duration of the study was further evaluated with Cox proportional hazards regression analysis. Creatinine concentration on admission and at discharge was compared with a paired *t* test.

Analyses were carried out with statistical software (SAS v. 9.4, SAS, Cary, North Carolina) and the level of statistical significance was set at .05.

## 3 | RESULTS

### 3.1 | Cohort

One hundred and seventeen SUB devices were placed in 81 cats during the study period. Of the 81 cats, 42 (52%) were spayed females and 39 (48%) were castrated males. Before surgery, median pelvic and ureteral measurements measured on ultrasound were 6.6 mm (range, 1.1-37 mm) and 3.2 mm (range, 0-11 mm), respectively. Forty-five (56%) cats had a unilateral obstruction and 36 (44%) a bilateral obstruction. Among the 36 bilateral SUB devices placed, 4 (11%) were placed on two separate occasions as unilateral ureteral obstructions occurred at different time points. Age at the time of SUB device placement was 9 years (median, range 2.5-17.2 years). Body weight at the time of the surgery was 4.1 kg (median, range 2.15-9.25 kg).

Ureteral obstruction was thought to be secondary to the presence of ureterolithiasis in 85/117 (73%) of the obstructed ureters, to a stricture in 18/117 (15%) cases, and pyelonephritis in 7/117 (6%). Combination of a pyelonephritis and a stricture was suspected in 3 cases. No etiology could be identified in 4 cases.

Anesthesia time in our population was 220 minutes (median, range 135-435 minutes) while surgery time was 155 minutes (median, range 75-370 minutes). Twenty out of 81 (25%) cats had another procedure at the same time of the SUB device placement: cystolith removal (16/20), intestinal biopsy (3/20), and bronchoalveolar lavage and intestinal biopsy (1/20).

On admission, PCV was 30% (median, range 15%-48%) and serum creatinine was 5.3 mg/dL (470  $\mu$ mol/L; median, range 1.2 to >15 mg/dL [108 to >1326  $\mu$ mol/L]). Urine culture obtained by cystocentesis in all cats before surgery was positive in 7/81 cats (9%) all of which administered antibiotics. None of these cats had a positive urine culture obtained by pyelocentesis at the time of surgery. Urine obtained by pyelocentesis at the time of SUB device placement (urine from both kidneys was pooled together in the case of a bilateral obstruction) was positive in 7/81 (9%) cats. The overall prevalence of a positive urine culture before surgery was 14/81 (17%). Bacteria cultured were *Escherichia coli* (*n* = 10), *Staphylococcus* spp. (*n* = 3), and *Enterococcus faecalis* (*n* = 1). Overall, 23 cats (28%) were receiving antibiotics at the time of presentation.

Cardiac ultrasound was performed on 49/81 (60%) cats with a heart murmur or suspected fluid overload. No underlying heart disease was found in 26/49 (53%) cats. Hypertrophic cardiomyopathy was diagnosed in 14/49 cats (29%), unclassified cardiomyopathy in 2/49, mitral valve dysplasia in 2/49, restrictive cardiomyopathy (*n* = 1), interventricular communication (*n* = 1), ventricular outflow tract obstruction (*n* = 1), intermittent systolic dysfunction (*n* = 1), and ischemic/myocarditis lesions (*n* = 1).

### 3.2 | Postoperative data

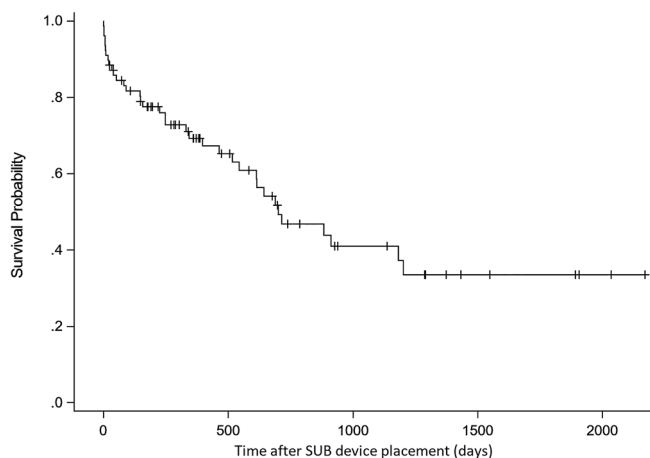
A SUB device was successfully placed in 117 kidneys. Seventy-six of 81 (94%) cats were discharged from the hospital. Hospitalization time was 3 days (median, range 1-11 days). Five cats died or were euthanized before discharge (refractory pulmonary edema [ $n = 1$ ], obstruction of the device by a blood clot [ $n = 1$ ], uroperitoneum [ $n = 1$ ], uremic coagulopathy leading to a disseminated intravascular coagulation [ $n = 1$ ], end-stage kidney disease [ $n = 1$ ]). No cat died of cardiac disease during hospitalization.

Serum creatinine concentration at the time of discharge was 2.1 mg/dL (186  $\mu$ mol/L; median, range 1.1-12.5 mg/dL [98-1104  $\mu$ mol/L]), which was significantly lower compared to the creatinine on admission ( $P < .001$ ).

A total of 37/81 (46%) cats required a blood transfusion. Median PCV before discharge was 24% (range, 16%-36%). There was no significant association between PCV on admission or at the time of discharge and serum creatinine on admission ( $r = -0.17$ ,  $P = .14$  and  $r = -0.16$ ,  $P = .17$ , respectively). Cats that received a blood transfusion had a significantly higher creatinine on admission ( $r_s = 0.44$ ,  $P < .001$ ). There was a significant positive association between the number of blood transfusions and creatinine at discharge ( $r_s = 0.53$ ,  $P < .001$ ).

### 3.3 | Outcome and risk factors

Overall, survival time of our cats was 821 days (mean, range 1-2170 days; Figure 1). Follow-up time after SUB device placement was 367 days (median, range 1-2170 days). After surgery, survival proportion was 94% (76/81) at discharge, 88% (71/81) at 1 month, 87% (67/77) at 3 months, 77% (56/73) at 6 months, and 70% (43/61) at 1 year after SUB device placement.



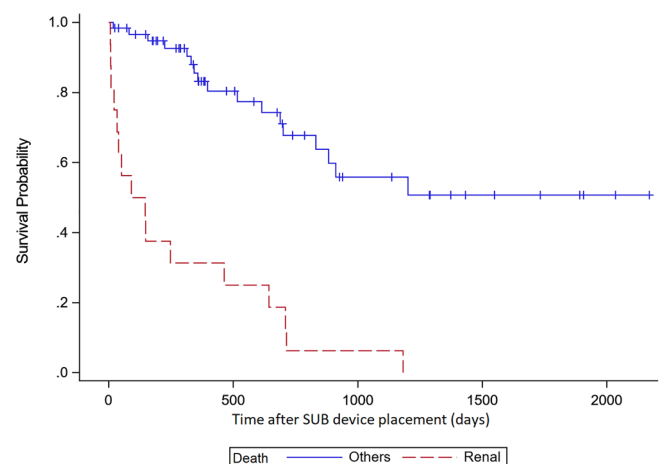
**FIGURE 1** Kaplan-Meier survival curves of 81 cats that underwent SUB device placement for treatment of benign ureteral obstruction (+: censored cats)

At the end of the study, 43 cats (53%) were alive and 38 (47%) died. Among those who died, 42% (16/38) died of renal-related causes: end-stage CKD (9/38, 24%), pyelonephritis (5/38, 13%), suspected renal-related death (2/38, 5%). In 4/38 cats (11%) an intraluminal obstruction of the SUB was diagnosed and the owners declined corrective surgery. The mean survival time (MST) of cats that died secondary to a urinary related cause was significantly shorter than for cats that died of nonurinary related causes (285 days vs 478 days,  $P = .003$ ; Figure 2).

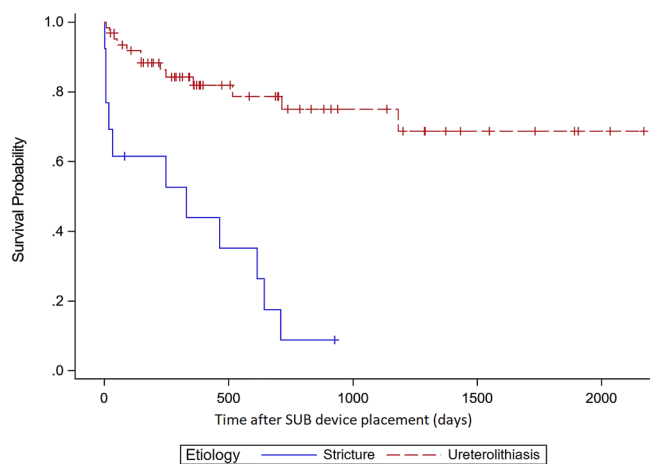
Overall, high concentrations of creatinine in serum at discharge ( $P < .001$ ; hazard ratio: 1.005; 95% confidence interval [CI] = 1.003-1.006), a greater number of blood transfusions required perioperatively ( $P = .009$ ; hazard ratio: 1.58; 95% CI = 1.12-2.22), ureteral obstruction secondary to a stricture versus a stone ( $P < .001$ ; hazard ratio: 6.33; 95% CI = 2.77-14.45) significantly decreased the survival time (Figure 3). Hospitalization time, need for darbepoetin injections, PCV on admission or at discharge, serum creatinine concentration at admission, anesthesia and surgery times, placement of a bilateral SUB device, size of pelvis on admission, a positive urine culture at the time of the surgery, and body weight were not significantly associated with survival time.

Survival time of cats in IRIS stage II based on the serum creatinine concentration 1 month after SUB device placement was 1181 days (median, range 82-1891 days). Survival time of cats in IRIS stage III based on the serum creatinine concentration 1 month after SUB device placement was 710 days (median, range 342-2170 days). No significant difference was found between those two stages ( $P = .83$ ). Too few IRIS stage I and IV cats were included in the study to calculate a median survival time.

Risk factors significantly associated with longer hospitalization time included the need for a blood transfusion ( $P < .001$ ) or darbepoetin injection ( $P = .006$ ), and higher level of serum creatinine on admission ( $P = .003$ ) and at discharge ( $P = .006$ ) as well as the



**FIGURE 2** Kaplan-Meier survival curves of 38 cats that underwent SUB device placement and that died during the follow-up based on the cause of death (urinary-related or others; +: censored cats)



**FIGURE 3** Kaplan-Meier survival curves of 81 cats that underwent SUB device placement based on the cause of the ureteral obstruction (ureterolithiasis or stricture; +: censored cats)

placement of a bilateral SUB device ( $P = .01$ ). No other risk factors influenced hospitalization time including body weight, anesthesia and surgery times, size of the pelvis on admission, etiology of the obstruction, a positive urine culture at the time of the surgery, and PCV on admission or at discharge.

### 3.4 | Complications

#### 3.4.1 | Perioperative complications

Twenty-five of 81 (31%) cats had a perioperative complication for a total of 31 complications, which included presence of an obstructive luminal or extraluminal blood clot ( $n = 5$ ), signs of LUTD ( $n = 6$ ), fluid overload ( $n = 4$ ), a kink of the catheter ( $n = 4$ , 3 nephrostomy tubes, 1 cystostomy tube), seroma ( $n = 3$ ), luminal obstruction ( $n = 2$ ), corneal ulcer ( $n = 2$ ), renal hematoma ( $n = 1$ ), renal necrosis and uroabdomen ( $n = 1$ ), generalized bleeding ( $n = 1$ ), intermittent hyperthermia ( $n = 1$ ), and seizure ( $n = 1$ ).

#### 3.4.2 | Short-term complications

Eleven of 76 (20%) cats had a short-term complication for a total of 14 complications, which included seroma ( $n = 5$ ), pyelonephritis ( $n = 2$ ), luminal obstruction ( $n = 2$ ), signs of LUTD ( $n = 2$ ), fluid overload ( $n = 1$ ), nephrogenic diabetes insipidus ( $n = 1$ ), and self-limiting subcapsular effusion ( $n = 1$ ).

#### 3.4.3 | Long-term complications

Forty of 71 (56%) cats had a long-term complication for a total of 52 complications. Obstruction of the device occurred in 24/101 SUB

devices, suspected to be secondary to a luminal obstruction by mineral debris in 16/101 SUB devices and a kink of the nephrostomy or the cystostomy tube in 8/101 SUB devices. A positive urine culture associated with clinical signs of an infection was documented in 18/71 (25%) cats and 10/71 (14%) cats had signs of LUTD with a negative urine culture. In the 18 cats with a positive urine culture and clinical signs, 14/18 cats had pyelonephritis and 4/18 a LUTI.

#### 3.4.4 | Overall

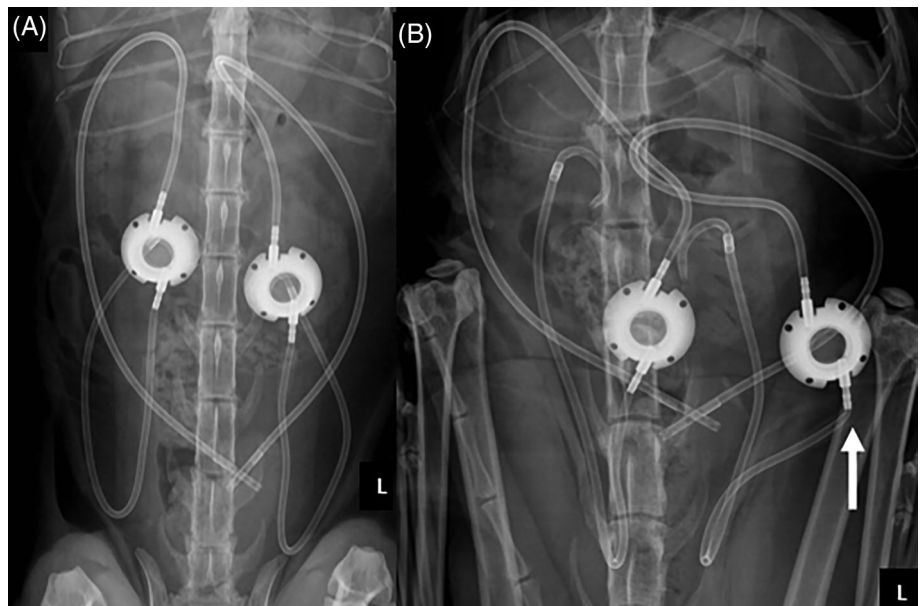
No device leakage was reported in this cohort perioperatively, in the short- or long-term follow-up. Luminal obstruction was documented in 18/109 (17%) SUB devices of 16 cats that were discharged from the hospital. Twelve obstructions occurred on the left side, 6 on the right side. In those, 8 had a patent ipsilateral ureter therefore no pelvic or ureteral dilatation was observed on ultrasound and no treatment was undertaken. In the 10/109 other cases presenting hydroureter/hydronephrosis in association with their luminal obstructions, 3 cats were euthanized and 5 required corrective surgery in order to exchange the obstructed port ( $n = 1$ ), nephrostomy catheter ( $n = 3$ ), or cystostomy catheter ( $n = 1$ ). Patency of the device was achieved with infusion of tEDTA in 2 cats. Time to luminal obstruction after discharge was 204 days (median, range 21-1678 days). Location of the obstruction was determined in 14 cases. Seven (50%) nephrostomy tubes and 3 (22%) cystostomy tubes were obstructed. Both tubes were obstructed in 2 (14%) cases. The subcutaneous port was the cause of obstruction in 2 cases (14%).

A kink of the catheters occurred in 12/117 (10%) SUB devices, 8 were from the left side, 4 from the right. A kink of the cystostomy catheter was reported in 4/12 cats, and 8/12 were from the nephrostomy catheter. Nine (75%) required a revision surgery to restore SUB patency. The remainder of the cats had a patent native ureter and no obvious pelvic or ureteral dilatation was noted. Two of these cats had positional kinks, suspected when suboptimal flushing was noted or pelvic/caliceal dilatation was observed despite normal flushing and drainage under ultrasound guidance. Positional kinks were confirmed with abdominal radiographs or fluoroscopic exams with the cat placed in a physiological/squatting position (Figure 4). Both cats underwent surgery to reposition the partially kinked catheters. Time to identifying a kink was 58 days (median, range 2-601 days), which was significantly lower than for the luminal obstruction (median 204 days; range, 21-1678 days;  $P = .03$ ).

Overall, location (cystostomy or nephrostomy catheter) and side (left or right) were not associated with a higher risk of kink or luminal obstruction ( $P = .93$  and  $P = 1$ , respectively).

Fourteen of 81 (17%) cats required a revision surgery in order to exchange a cystostomy or nephrostomy catheter due to the presence of a kink (9/14) or luminal obstruction (5/14). Eleven of 14 (79%) required 1 surgery, 1 required 3 surgeries in order to correct 1 intraluminal obstruction and 2 kinks at different time points in the follow-up period. Two cats underwent 4 revision surgeries to correct recurrent kinks ( $n = 1$ ) or recurrent luminal obstructions ( $n = 1$ ).

**FIGURE 4** Abdominal radiographs of a cat with a partial and positional right nephrostomy tube kink (A: Standard X-rays; B: Positional X-rays). A white arrow is pointing at the kink in the nephrostomy catheter



Seven obstructions of the device by a blood clot were treated with a tissue plasminogen activator (TPA) infusions into the SUB port (0.5-1 mg TPA infused q24h-q12h until restored patency). One cat underwent a corrective surgery due to a blood clot obstruction, as the whole device was obstructed, 24 hours after its SUB device placement.

An infection—pyelonephritis or LUTI—was reported in 20 of 76 (26%) cats during the follow-up period. Time to identifying an infection was 150 days (median, range 14-607 days). Pyelonephritis was suspected in 16/76 (21%) cats and LUTI in 4 (5%) cats. In 7 of 76 (9%) cats, more than 1 infection was documented during the follow-up period. Six cats had separated infection events while 1 cat was treated for a chronic 1. Most common isolated bacteria for urinary infection were *E coli* ( $n = 14$ ) and *E faecalis* ( $n = 4$ ).

A positive urine culture in the absence of clinical signs was documented in 6/76 (8%) cats on 17 different occasions. No increase in serum creatinine concentration was observed in these cats. Isolated organisms for those SB were *E coli* ( $n = 12$ ) and *E faecalis* ( $n = 5$ ).

Cats with a positive urine culture at the time of the surgery were significantly more likely to have an infection during the follow-up period (38% vs 7%,  $P = .01$ ). Among the 7 positive bacterial cultures obtained from pyelocentesis, 3 (42%) had another infection during the follow-up period ( $n = 1$ : different bacteria,  $n = 2$ : same bacteria).

### 3.5 | Follow-up information

No cat was lost during the follow-up period. For cats that died outside of our facility, the primary veterinarian was contacted to identify the cause of death.

When examining whether or not the creatinine would remain above or below 2.8 mg/dL (250  $\mu$ mol/L) after surgery, there was strong agreement found between creatinine IRIS stage at 1 month

and at 3 months after discharge ( $\kappa = 0.83$ ): all cats (23/23) with a creatinine <2.8 mg/dL (250  $\mu$ mol/L) remained below this cutoff at 3 months and 7/9 with a higher creatinine level remained high. Substantial agreement was found between creatinine IRIS stage at 1 and 12 months ( $\kappa = 0.67$ ): 22/23 cats with a creatinine <2.8 mg/dL (250  $\mu$ mol/L) remained below this cutoff at 12 months whereas 6/9 with a higher creatinine level remained high.

## 4 | DISCUSSION

Immediate renal pelvis decompression was observed after SUB device placements, resulting in a decrease in serum creatinine concentration in all cats except 2. Results of this study demonstrate that SUB device placement is a good therapeutic option in cats with BUO, in agreement with previous studies, resulting in immediate relief of obstruction and decrease in creatinine.<sup>8,12,14,20</sup>

A SUB device was successfully placed in all cats, and 94% were discharged from the hospital. A similar success rate was described previously.<sup>8</sup>

In our study, the need for a blood transfusion, darbepoetin injection, a bilateral SUB device, or creatinine on admission and at discharge were all significantly associated with a longer hospitalization. Cats presenting with a higher creatinine needed more transfusions and had esophagostomy tubes placed both of which could have contributed to longer hospital stays to ensure cats were receiving adequate nutrition and were stable to leave the hospital. Other factors such as positive urine culture, duration of obstruction, development of fluid overload during hospitalization, or serum blood urea nitrogen concentration on admission were also noted to have an influence on the duration of hospitalization in another study.<sup>8</sup>

Our overall MST was 821 days, whereas a median survival of 827 days has been reported.<sup>8</sup> No median survival time could be

calculated as our cases were censored due to nonurinary related causes of death and a high number of cats still alive at the end of the study. A longer follow-up period might have allowed calculation of a median survival time. Risk factors associated with survival include a history of CKD, weight loss, and the development of fluid overload during hospitalization.<sup>8</sup> Few of our cats had fluid overload ( $n = 5$ ) while hospitalized. Performing a cardiac exam in cats presenting with heart murmurs can provide guidance to the clinician to better adjust fluid therapy during the pre- and perioperative periods, thus optimizing hydration and avoiding fluid overload. In our study, the need for a blood transfusion was associated with survival and could be explained by these cats being in a more critical clinical condition. Serum creatinine concentration at discharge was also associated with survival. This suggests that the higher the creatinine is at discharge, the more severe the kidney disease will remain. This is also suggested by the overall stability of the creatinine 1 month after surgery. Presence of a stricture was associated with a shorter survival time compared to ureteral obstruction secondary to urolithiasis. We hypothesize that an obstruction by a stone might result in a more acute kidney injury compared to a ureteral stricture that might lead to a more chronic obstruction and CKD. As strictures can be more difficult to identify, delayed diagnosis of ureteral obstruction might also have contributed.

The median survival time of cats with IRIS stage II and III were 1181 days and 710 days, respectively. In a previous retrospective study of cats with CKD, similar median survival time was found. Cats with IRIS stage II CKD have a median survival time of 1151 days, and cats with IRIS CKD have a median survival time of 778 days.<sup>25</sup> There is a longer median survival time for cats with a SUB device in IRIS stage I or II CKD (2251 days and 2397 days, respectively) 3 months postprocedure as compared to those with naturally occurring CKD.<sup>8,25</sup> This longer survival time could be secondary to the longer follow-up, as most IRIS stage I and II CKD cats were still alive at the end of our study. These results suggest that placement of a SUB device does not affect overall survival in cats with CKD. Long-term serum creatinine concentration can be predicted based on the serum creatinine concentration at 1 month after surgery. This suggests an overall stability of the serum creatinine concentration despite acute renal injury secondary to ureteral obstruction and trauma to the kidney after SUB device placement.

SUB device placement is a good option for treatment of BUO and provides excellent outcomes as the majority of cats will die of non-urinary related causes (58%, 22/38).

In our study, the median dilatation of the renal pelvis was 6.6 mm (range, 1.1–37 mm), which is lower than reported.<sup>8,12,20</sup> The preoperative pelvic size did not affect survival and SUB device placement should be considered in any kidney regardless of pelvic size if ureteral obstruction is identified. Ureteral obstruction could be present in cats despite minimal pelvic dilatation. Those cats with minimal pelvic dilatation can be a diagnostic and therapeutic challenge. In a recent study done at the same facility on a similar cohort, ureteral distension as well as dilatation of pelvic diverticula was used to help diagnose ureteral obstruction when minimal pelvic dilatation was present.<sup>9</sup> There is a negative correlation between renal pelvis size and serum

creatinine concentration.<sup>9</sup> Lack of pelvic dilatation might be secondary to capsular or parenchymal fibrosis preventing expansion.

Previous studies have reported higher proportions of positive urine cultures at surgery (25%)<sup>8,14</sup> than in our study (17%). A recent study found an even lower preoperative proportion of positive urine cultures (12.7%), but no information regarding preadmission administration of antibiotics was provided in this study.<sup>10</sup> The high proportion of cats (28%, 23/81) receiving antibiotics before presentation to our hospital could have resulted in false negatives. In our study, a positive urine culture at surgery was associated with a higher risk of postoperative infection during follow-up. Bacteriuria at surgery is associated with a higher chance of bacteriuria at repeat examination.<sup>8,10</sup> Cats with a positive urine culture at the time of surgery should be closely monitored for signs of infection thereafter as up to 24% will have another positive urine culture within a year.<sup>10</sup> Urinary tract infections in the presence of a SUB device can be effectively cleared in most cases as only 1 cat in our study required long-term antibiotics for a recurrent infection by the same pathogen.

Similarly to other studies, signs of LUTD was documented in 14% (10/71) of our cats in the long term.<sup>8,12,20</sup> Some cats might have LUTD that could have been worsened with placement of the SUB device. Unfortunately, this information was not available in our cohort. Cats in our study had straight bladder catheters placed. The tip of the catheter may irritate the bladder trigone and contribute to signs of LUTD. In most cats, clinical signs were managed with gabapentin or buprenorphine as needed. No cat underwent trimming of their cystostomy tube. Recently, straight bladder catheters have been replaced with locking loop catheters or shorter straight bladder catheters and might result in less bladder irritation.

Luminal obstruction suspected to be due to mineralized debris in 18/109 SUB devices (17%). This rate is lower than previously reported.<sup>8</sup> Median time to occurrence of luminal obstruction was 204 days which was shorter than previously described (463 days).<sup>8</sup> Hypotheses for this could be the shorter follow-up or environmental factors (water, diet) considering that SUB flushes were performed at the same frequency in both studies. Other factors such as increased urine mineral excretion in the study population could also have contributed to increased intraluminal mineralization. More recently, serum ionized calcium concentration has been monitored in cats with SUB devices as hypercalcemia has been associated with a higher prevalence of mineralization.<sup>8</sup> However, no data was available for our cohort.

A number of SUB devices obstructed by mineralization (44%, 8/18) had evidence of a patent native ureter as no renal pelvic or ureteral dilatation was present. This has also been reported and explained by ureterolith passage after SUB placement.<sup>8</sup> Therefore, it is essential to document the absence of ureteral obstruction in the presence of an obstructed SUB device as no further intervention (use of tEDTA, surgery) is recommended.

Our study has a number of limitations. The moderate sample size and the lack of information regarding previous history of CKD, as well as other variables (hypercalcemia, location of nephrostomy catheter in the ureter vs the pelvis), could have influenced the results. The use of

the PCV on admission might not be the most accurate because dehydration/overhydration at the time of presentation is a common finding; however, it is helpful for the clinician to know that PCV on admission does not predict outcome. A longer follow-up period could have helped better characterize overall survival, time to occurrence of complications, and survival times of our cats according to their IRIS CKD stage. The difference between a LUTI and a pyelonephritis might not always be clear cut and some cases classified as having LUTI could have had clinically undetectable pyelonephritis as the SUB device connects the kidney to the bladder. Despite these limitations, we felt that dividing cats into LUTI and pyelonephritis was clinically relevant.

In conclusion, SUB device placement is a good treatment option for cats with BUO; however, its placement can be technically challenging and should be performed by trained veterinarians. It provides a good outcome and survival as well as a decrease in serum creatinine concentration in the majority of cats. Complications occur frequently but can be managed medically or occasionally with surgical revision when required. Subcutaneous ureteral bypass device placement is associated with good long-term survival in cats in which ureteral obstruction was a life-threatening condition at the time of diagnosis. Overall, 24% of cats with a SUB device will die due to progression of their CKD, however not at an accelerated rate compared to a natural occurring kidney disease despite the presence of the SUB device. Monitoring and treatment of their CKD along with ensuring SUB patency likely contribute to a favorable outcome.

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#### CONFLICT OF INTEREST DECLARATION

Authors declare no conflict of interest.

#### OFF-LABEL ANTIMICROBIAL DECLARATION

Authors declare no off-label use of antimicrobials.

#### INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Authors declare no IACUC or other approval was needed.

#### HUMAN ETHICS APPROVAL DECLARATION

Authors declare human ethics approval was not needed for this study.

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## SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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