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Clinical Presentation and Outcome of Cats with Circumcaval Ureters Associated with a Ureteral Obstruction

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Background: Circumcaval ureters (CU) are a rare embryological malformation resulting in ventral displacement of the caudal vena cava, which crosses the ureter, potentially causing a ureteral stricture.

Objectives: To evaluate cats with obstructed CU(s) and report the presenting signs, diagnostics, treatment(s), and outcomes. Cats with obstructed CU(s) were compared to ureterally obstructed cats without CU(s).

Animals: 193 cats; 22 circumcaval obstructed (Group 1); 106 non-circumcaval obstructed (Group 2); 65 non-obstructed necropsy cases (Group 3).

Methods: Retrospective study, review of medical records for cats treated for benign ureteral obstructions from AMC and University of Pennsylvania between 2009 and 2013. Inclusion criteria: surgical treatment of benign ureteral obstruction, complete medical record including radiographic, ultrasonographic, biochemistry, and surgical findings.

Results: Seventeen percent (22/128) of obstructed cats had a CU (80% right-sided) compared to 14% (9/65) non-obstructed necropsy cats (89% right-sided). Clinical presentation, radiographic findings, and creatinine were not statistically different between Groups 1 and 2. Strictures were a statistically more common (40%) cause of ureteral obstruction in Group 1 compared to Group 2 (17%) ($P = .01$). The MST for Groups 1 and 2 after ureteral decompression was 923 and 762 days, respectively ($P = .62$), with the MST for death secondary to kidney disease in both groups being >1,442 days. Re-obstruction was the most common complication in Group 1 (24%) occurring more commonly in ureters of cats treated with a ureteral stent(s) (44%) compared to the subcutaneous ureteral bypass (SUB) device (8%) ($P = .01$).

Conclusions and Clinical Importance: Ureteral obstructions in cats with a CU(s) have a similar outcome to those cats with a ureteral obstruction and normal ureteral anatomy. Long-term prognosis is good for benign ureteral obstructions treated with a double pigtail stent or a SUB device. The SUB device re-obstructed less commonly than the ureteral stent, especially when a ureteral stricture was present.

Key words: Double pigtail stent; Retrocaval; Subcutaneous urteral bypass; Venous malformation.

Circumcaval ureters, otherwise known as retrocaval ureters, are a rare embryological venous malformation resulting in dorsal displacement of the ureter to the caudal vena cava.[1–3] There are 3 embryologic venous systems: posterior cardinal, subcardinal, and supracardinal, which form the vena cava.[4] If during development there is persistence of the right posterior cardinal vein the ureter will have a more dorsal position.[5–9]

The incidence of CU in people is approximately 1 : 1,000, with males having a 3- to 4-fold predominance.[10] In humans the disease is typically silent until the 3rd or 4th decade of life.[11–13] This condition is most commonly right-sided,[13] with a left-sided lesion most often associated with situs inversus or caval duplication.[8,14] Additionally, CU have been associated with other urogenital abnormalities (eg, renal agenesis).[15,16] Two types of CUs are described in people; Type I (low loop; 90% of cases) results in a "fish-hook" or "s" shape appearance of the middle segment of the ureter where 50% develop hydronephrosis, and Type II (high loop) the ureter crosses the cava at the UPJ, resulting in minimal to no dilation.[13,17,18] Laparoscopic ureteral transposition and re-anastamosis over a ureteral stent is the most common treatment of obstructed CU in people.[6,19]

Ureteral obstructions secondary to ureterolithiasis are a common cause of acute azotemia in cats.[20–24] Congenital or acquired strictures, trigonal neoplasia, trauma, ureteritis, and dried solidified blood clots, have also been reported as causes of ureteral obstruction(s).[20–28] In 1922 a CU was described in a cat.[29] In 2011, obstructive feline ureteral strictures were reported in 10 cats,[25] with 40% having a CU. Additionally, a series[30] of necropsy cats were evaluated and 35.2% were found to have at least one CU.

The objective of this report was to describe the clinical presentation, diagnostic imaging findings, and treatment outcomes in cats with a ureteral obstruction(s) and associated CU(s). The outcome parameters were compared to a group of cats with a ureteral obstruction

Abbreviations:

AMC	Animal Medical Center
BUN	blood urea nitrogen
CU	circumcaval ureter
IHD	intermittent hemodialysis
MST	median survival time
SUB	subcutaneous ureteral bypass device
UPJ	ureteropelvic junction

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(s) without a CU. The hypotheses for this study were 4-fold: (1) CU are a common finding in obstructed feline ureters; (2) the presence of a CU is commonly associated with a ureteral stricture; (3) the survival in ureterally obstructed cats after surgically-assisted interventional management (double pigtail stent [2.5 French Double Pigtail ureteral stent[a]] or subcutaneous ureteral bypass [SUB] device[b]) is similar, regardless of the presence of a CU(s); (4) complications in ureterally obstructed cats with a CU are higher with a double pigtail ureteral stent compared to a SUB device.

Materials and Methods

Criteria for Selection of Cases

Medical records of cats treated for a benign ureteral obstruction by the authors (ACB and CW) between 2009 and 2013 were retrospectively evaluated from the Animal Medical Center (AMC), New York and The Matthew J. Ryan Veterinary Hospital of the University of Pennsylvania. Cats were included in the study if they were surgically treated for a benign (stone, stricture, debris) ureteral obstruction. A complete medical record had to be available for review including the pre-operative biochemical and microbiological data, pre-operative imaging findings, and a surgical report documenting ureteral anatomy and treatment (eg, ureteral stent, SUB, or ureteral reimplantation/ureterotomy). A portion of cats from a previous study[26] were included in this study because the previous study looked at the feasibility of ureteral stenting and did not differentiate between CU and non-CU cases. Furthermore, the previous study did not include patients treated with a SUB device, which were included in this study. The incorporation of these previously reported cases allowed for improved statistical comparisons between CU and non-CU cats.

An additional observational study was conducted through the pathology service at the AMC from October 2012 through August 2013. All cats that presented to the pathology service for necropsy were examined for the presence of a CU(s). For all patients that had a CU identified a 0.018″ angle-tipped hydrophilic guide wire (0.018 in. Weasel wire[a]) was passed from renal pelvis to bladder (antegrade) to determine the patency of the ureter. When the guidewire was not available, the ureters were examined grossly for evidence of obstruction. Renal pelvis size and ureteral dilation were evaluated in all ureters to determine if there was evidence of a ureteral obstruction based on concurrent hydronephrosis and hydroureter. Data collected in the necropsy study included age, sex, breed, cause of death, presence of a ureteral obstruction (based on ureteral patency with a guide wire) and ureteral and urogenital anatomy.

The cats were divided into 3 groups throughout the study. *Group 1* were the cats with a ureteral obstruction associated with a documented circumcaval ureter. This group included 7 cases treated with a double pigtail stent from a previous study[26]; *Group 2* were the cats with a ureteral obstruction without a circumcaval ureter. This group included 55 cases treated with a double pigtail stents from a previous study[26]; *Group 3* were non-obstructed cats in the necropsy group.

Procedures

Information retrieved from the medical records for cats in Groups 1 and 2 included signalment, history, physical examination findings, clinical laboratory results, urine microbiologic evaluation, diagnostic imaging findings including renal pelvis and ureteral diameter measurements, pre-operative management (eg, intermittent hemodialysis, previous ureteral surgery), surgical findings (eg, ureteral anatomy, location and laterality of obstruction), cause of obstruction (eg, stone, stricture), and method of treatment. The cause of the obstruction was determined based on a combination of radiograph, ultrasound, and antegrade pyelography imaging. If an obstruction was present on the pyelogram without the presence of a stone in the lumen based on contrast and surgical exploration/palpation at that location, a presumptive diagnosis of a ureteral stricture/stenosis was made. Peri-operative (<7 days), short-term (7 to ≤30 days) and long-term (>30 days) complications (eg, re-obstructions, stent migration, etc.) were documented. Overall survival, cause of death, and creatinine concentrations at discharge, 3, 6, and 9 months were also recorded. Technical details on the placement of various devices for the treatment of feline ureteral obstructions are described elsewhere.[23,26,27] All patients were discharged on a minimum 2 weeks course of antibiotics following placement of a device (Stent/SUB).

Statistical Analysis

Statistical software was used for all analyses.[c] Results were considered statistically significant at $P \leq .05$. Continuous data were compared among and between the three groups using the Kruskal-Wallis and Mann-Whitney *U*-tests, respectively. Chi-square (or Fisher's exact) tests were used to compare proportions among and between groups. Linear associations between continuous variables were assessed with Spearman's rank correlation. Survival times were calculated for patients in Groups 1 and 2 and, for the purposes of survival analysis, cats that were still alive at the end of the study period and cats that were lost to follow-up were censored. Survival times were expressed as median (95% CI). Kaplan-Meier curves and log-rank tests were used to compare survival times amongst the two groups.

Results

Selection of Cases

One hundred and ninety-three cats met the criteria for inclusion in this study including 22 circumcaval obstructed cats (Group 1), 106 non-circumcaval obstructed cats (Group 2) and 65 necropsy cats (Group 3). The sex (Group 1: 12 males:10 females; Group 2: 55 males:51 females; Group 3: 30 males:35 females) and median ages (Group 1: 8.7 years [range 0.6–16.2]; Group 2: 8.8 years [range 0.8–18]; Group 3: 11 years [range 0.6–17]) were not statistically different between the three groups, however the median body weight (Group 1: 4.8 kg [range 2.1–6.4]; Group 2: 4.1 kg [range 1.7–10]; Group 3: 3.4 kg [1.4–9.3] for Group 3 was significantly (P = .007) lower compared to Group 1 (P = .0055) and Group 2 (P = .01). The median body weights of the patients in Groups 1 and 2 were not significantly different.

Historical and Presenting Clinical Data

A history of a previous ureteral obstruction(s) was documented in 14% (3/22) of cats in Group 1 and 6% (6/106) in Group 2; a previous diagnosis of chronic kidney disease was made in 73% (16/22) in Group 1 and 53% (56/106) in Group 2; and a history of urolithiasis (nephrolithiasis, ureterolithiasis, or urocytolithiasis) in

23% (5/22) of cats in Group 1 and 9% (10/106) in Group 2. This historical data was not significantly different between Group 1 and Group 2 ($P \geq .61$). Two cats in Group 1 were uninephric; one being a previous kidney transplantation donor and one born with unilateral renal agenesis.

The most common clinical signs in Group 1 included a decreased appetite in 82% (18/22), lethargy in 64% (14/22), weight loss in 64% (14/22), and vomiting in 41% (9/22). The presenting clinical signs were not significantly different between Groups 1 and 2.

Clinicopathologic, Imaging Data, and Pre-operative Management

In Group 1, 95% of the cats had an increased creatinine at presentation. The median creatinine was 4 mg/dL (range 1.8–23.1 mg/dL). In Group 2, 96% of the cats had an increased creatinine at presentation with a median creatinine of 5.1 mg/dL (range 1.4–24.8 mg/dL). There was no significant difference between the groups ($P = .48$). Nine percent (2/22) of the cats in Group 1, and 21% (22/106) of the cats in Group 2, had a positive urine culture at the time of diagnosis ($P = .25$).

On ultrasound the median diameter of the renal pelvis, on transverse imaging, and ureter was 1.1 cm (range 0.4–2.5 cm) and 0.5 cm (range 0.2–1.4 cm), respectively, for Group 1 and 1.1 cm (range 0.3–2.9 cm) and 0.36 cm (range 0.1–1.8 cm), respectively, for Group 2 ($P = .97$). The diameter of the renal pelvis was not associated with creatinine ($P = .58$). The length of ureteral dilation from the UPJ to the site of obstruction was a median of 2 cm (range 1–3.5 cm) on the right and 2.8 cm (range 1–3.5 cm) on the left for Group 1.

Based on ultrasonographic and radiographic evaluation 64% (14/22) of the obstructed cats in Group 1 and 58% (62/106) in Group 2 had concurrent nephroliths ($P = .65$). In Group 1, 60% (9/15) of the cats with ureterolithiasis-induced obstructions alone had concurrent nephroliths and 59% (51/86) of the cats in Group 2 with ureterolithiasis-induced obstructions had concurrent nephroliths ($P = .61$). Overall, 59% (60/101) of the patients with ureterolithiasis, and 59% (16/27) of cats with strictures with or without ureterolithiasis, had concurrent nephroliths.

Frequency of CUs

Overall, 31 of 193 (16%) cats (34/382 ureters; 9%) in this study had a CU(s) (Table 1). The frequency of CU(s) in Group 3 was 14% (9/65 cats) whereas the frequency of CU(s) in the obstructed patients (Group 1 and 2) was 17% (22/128 cats) (Table 1) ($P = .83$). Three of 22 circumcaval cats (13.6%) had bilateral CUs totaling 34 CUs in the study population.

In Group 3, 7% (9/130) of the ureters were circumcaval, whereas 15% (25/164) of obstructed ureters in Groups 1 and 2 were circumcaval ($P = .03$), which is significantly significant.

Table 1. Frequencies of circumcaval and obstructed ureters.

	Group 1[a]	Group 2[b]	Group 3[c]	Total
Cats	22	106	65	193
Ureters	42	210	130	382
Circumcaval ureters	25	0	9	34
Right circumcaval ureters	20	0	8	28
Left circumcaval ureters	5	0	1	6
Obstructed ureters	30[d]	134	0	164
Right obstruction	20	64	0	84
Left obstruction	10	70	0	80

[a]Circumcaval obstructed (CU).
[b]Non-circumcaval obstructed (non-CU).
[c]Necropsy.
[d]In Group 1 five cats had bilateral ureteral obstructions where one ureter was circumcaval and the other ureter was normal. There are a total of 139 non-circumcaval obstructed ureters in this study (Group 1 and Group 2).

In Group 1, 71% (30/42) of the ureters were obstructed, 67% right and 33% left-sided (Table 2). Twenty-five of the obstructed ureters were circumcaval, with 80% (n = 20) on the right and 20% (n = 5) on the left. There were 5 non-circumcaval obstructed ureters in Group 1 (ie, bilaterally obstructed patients with one circumcaval and one normal ureter). In Group 2, two hundred and ten ureters were evaluated, 64% (134/210) of the ureters were obstructed, 48% right and 52% left-sided (Table 2). When the bilaterally obstructed cats (Group 1 n = 3; Group 2 n = 28) are

Table 2. Causes of obstructions and treatments for circumcaval (Group 1) and non-circumcaval obstructed (Group 2) ureters.

	Group 1	Group 2	*P*-Value
Obstructions			.18[a]
Stone (%)	15 (60)	115 (83)	
Stricture (%)	6 (24)	13 (9)	.01
Stone/stricture (%)	4 (16)	11 (8)	
Total	25	139[b]	
Treatments			.32
Double pigtail stent (%)	12 (48)	81 (57)	
Stone	7 (58)	67 (82)	
Stricture	3 (25)	6 (8)	
Stone/stricture	2 (16)	8 (10)	
SUB (%)	13 (52)	57 (42)	
Stone	9 (69)	47 (83)	
Stricture	2 (15.5)	7 (12)	
Stone/stricture	2 (15.5)	3 (5)	
Medical management (%)	0 (0)	1 (1)	

[a]There was no difference ($P = .18$) when looking at the stones, strictures, strictures/stones between the 2 groups, however Group 1 was more likely to have a stricture when compared to Group 2 ($P = .010$).
[b]139 ureters included in this table as 5 ureters were obstructed from Group 1 that were not circumcaval (the contralateral ureter that was bilaterally obstructed).

removed, circumcaval ureterally obstructed cats were more likely to be obstructed on the right side (89%; 17/19) compared to non-circumcaval obstructed cats (42%; 33/78; $P < .001$). In Group 3, 89% (8/9) of the CU were on the right side and 11% (1/9) on the left side. At the time of necropsy, a guidewire could be passed from the renal pelvis to the bladder in all patients examined and were considered to be non-obstrcuted.

Operative Findings and Management

In Group 1, there were 25 obstructed CU, of which 60% (15/25) were caused by ureteral calculi and 40% (10/25) a presumptive stricture(s) with or without concurrent ureteral calculi (Table 2). Group 2, there were 139[d] obstructed non CU of which 83% (115/139) were caused by ureteral calculi and 17% (24/139) were presumed to be associated with a stricture with or without concurrent ureteral calculi (Table 2). Circumcaval obstructed ureters were more likely to be secondary to a presumptive stricture (alone or with ureteral calculi) when compared to obstructed ureters that were not circumcaval ($P = .01$).

In Group 1, the 25 obstructed CUs were treated with 12 double pigtail ureteral stents (48%) and 13 SUB devices (52%) (Tables 1, 2). In Group 2, 99% (138/139) of the obstructed ureters were treated with either a double pigtail ureteral stent (n = 81, 57%) or a SUB device (n = 57, 42%) (Table 2). One obstructed ureter was successfully treated medically. There was not a significant difference in the treatment modalities between Groups 1 and 2.

Post-operative Data

In Group 1, 86% (19/22) of cats survived to discharge with a median hospitalization time of 4 days (range 2–25 days). The cause of death in the 3 cases that did not survive was failure of improvement in renal function (n = 2) and congestive heart failure (n = 1). In Group 2, 93% (99/106) of cats survived to discharge with a median hospitalization time of 4 days (range 2–13 days). The cause of death in the 7 cases that did not survive was pancreatitis (n = 3), congestive heart failure (n = 2), and failure of improvement in renal function (n = 2). Overall, 4 of 128 cats (3%) with a ureteral obstruction did not survive to discharge due to failure of renal function improvement.

Complications

Complications in Group 1 associated with the treatment of the ureteral obstruction were seen in 3 of 22 cats peri-operatively (<7 days). These included dislodgement of a nephrostomy catheter (1/22) and congestive heart failure (2/22) likely due to fluid overload. In the short term (7–30 days) a complication was seen in 2 of 19 cats including a positive urine culture (1/19) and dysuria (1/19). In the long-term (>30 days) complications were seen in 10 of 19 (53%) cats including dysuria (3/19), stent migration (1/19), ureteral tissue proliferation (1/19), and ureteral re-obstruction (5/21).

There were 5 (24%) re-obstructions in Group 1 and 26 (19.7%) re-obstructions in Group 2 (Table 3). Overall, when both groups were combined for treatment with stents (n = 86), SUBs (n = 66), or medical management alone (n = 1), 20% (31 of 153) of obstructed ureters re-obstructed (stents [26%], SUBs [13.6%] [$P = .09$]).

In the ureters obstructed by stricture (with or without ureteral stones) in Groups 1 and 2 that were treated with double pigtail stents, 8 (44%) of the stents re-obstructed (Table 3). In the ureters obstructed by ureteral calculi in Groups 1 and 2 treated with double pigtail stents, 14 (21%) of the stents re-obstructed (Table 3, $P = .04$).

In the ureters obstructed by strictures (with or without ureteral stones) in Groups 1 and 2 that were treated with a SUB device, 1 of 12 (8%) of the SUB devices re-obstructed. In the ureters obstructed by ureteral calculi in Groups 1 and 2 treated with a SUB

Table 3. Re-obstructions in circumcaval (Group 1) and non-circumcaval Obstructed (Group 2) ureters in cats that survived to discharge.

	Group 1	Group 2	*P*-Value
Ureteral obstructions surviving to discharge	21	132	.06
Double pigtail stents (%)	9 (75)	77 (95)	
Stone	5 (71)	63 (94)	
Stricture	2 (67)	6 (100)	
Stone/stricture	2 (100)	8 (100)	
SUB (%)	12 (92)	54 (95)	
Stone	9 (100)	45 (96)	
Stricture	1 (50)	6 (86)	
Stone/stricture	2 (100)	3 (100)	
Medical management (%)	1 (100)		
Primary condition that re-obstructed[a]			.12[b]
Double pigtail stent (%)	4 (44)	18 (23)	.04[c]
Stone	1 (20)	13 (21)	
Stricture	2 (100)	3 (50)	
Stone/stricture	1 (50)	2 (25)	
SUB (%)	1 (8)	8 (15)	.68
Stone	1 (8)	7 (16)	
Stricture	0 (0)	0 (0)	
Stone/stricture	0 (0)	1 (33)	
Medical management (%)	0	0	
Total (%)	5 (23)	26 (19.7)	.66
Causes of re-obstructions			.005[d]
Double pigtail stent	4	18	
Stone (%)	1 (24)	9 (50)	
Stricture ± stone (%)	3 (75)	9 (50)	
SUB (%)	1	8	
Stone	1 (100)	8 (100)	
Stricture ± stone	0 (0)	0 (0)	

[a]Initial presenting cause of obstruction which subsequently re-obstructed.

[b]No difference between Stents and Sub re-obstructions.

[c]Stones versus strictures with or without stones.

[d]Stents were more likely to re-obstruction secondary to a stricture compared to SUBs.

device, 8 of 53 (15%) of the devices re-obstructed (Table 3, $P = .68$).

The cause of a re-obstruction in stented ureters was secondary to a stricture in 55% of re-obstructed ureters and secondary to a stone in 45% of re-obstructed ureters (Table 3). The cause of the re-obstruction of a SUB device was secondary to a stone (within the SUB device) in 100% of cases that re-obstructed. Ureteral stents were significantly more likely to re-obstruct secondary to a stricture compared to a SUB device ($P = .01$).

Follow-up

In Group 1, the median creatinine at presentation (4 mg/dL; range 1.8–23.1 mg/dL) was not significantly associated with the creatinine at discharge (median 2.5 mg/dL; range 1.4–5.6 mg/dL; $P = .41$, rho = 0.19) or creatinine at 3 months (median 2.0 mg/dL; range 1.5–5 mg/dL; $P = .34$, rho = 0.24). Overall, there was not a significant difference between Groups 1 and 2 for creatinine concentration at discharge or creatinine at 3 months.

When patients were evaluated for the presence of a positive urine culture on presentation there was not a significant difference in length of hospitalization, survival to discharge, creatinine at discharge, creatinine at 3 months, or the risk of re-obstructions ($P \geq .54$).

Survival

A Kaplan–Meier survival curve for Group 1 and Group 2 is shown in Figure 1. The median survival time (MST) was 923 days (95% CI 491 days, range 2 to >1,442 days) for Group 1 and 762 days (95% CI 418 days, range 2 to >1,790 days) for Group 2. There was not a significant difference in MST between the two groups ($P = .62$). Of the 22 cats in Group 1, 13 died or were euthanized, and 2 were lost to follow-up. The cause of death was associated with the progression of kidney disease in 23% (3/13) of the cats that died or were euthanized in Group 1. Of the 106 cats in Group 2, 49 died or were euthanized, and 5 were lost to follow-up. The cause of death was considered associated with progression of kidney disease in 14% percent (7/49) of the cats that died or were euthanized. The follow-up time for Groups 1 and 2, when only renal cause of death was evaluated, was over 1,442 days, as less than 50% of patients were dead at the conclusion of this study.

Discussion

Results from this study suggest that CUs are a congenital abnormality, more commonly seen than previously recognized in both ureterally obstructed and non-obstructed cats. They should be considered in any ureterally obstructed cat, especially when a proximal right-sided ureteral obstruction is diagnosed and no stone is seen at the site of obstruction on diagnostic imaging. The obstruction in cats with a CU are more commonly associated with a stricture (40%) than is a non-circumcaval ureteral obstruction (17%). Age, sex, presenting clinical signs, biochemical, and ultrasound findings do not seem to distinguish between circumcaval and non-cirucmcaval ureterally obstructed cats. There is no significantly statistical difference in MST between cats with a circumcaval and non-circumcaval obstructed ureter(s) treated with either a stent or a SUB device. The most common complication seen in feline ureteral obstruction cases treated with either a stent or a SUB device was re-obstruction. Re-obstructions occur more commonly with a double pigtail ureteral stent than a SUB device, especially when used to treat a ureteral stricture.[26,31]

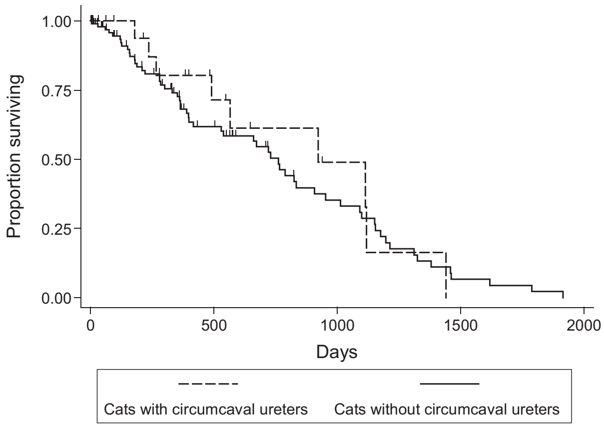

Fig 1. Kaplan-Meier survival curves for cats with circumcaval ureters (Group 1) and cats without circumcaval ureters (Group 2).

In this study, the frequency of a CU in non-obstructed cats was 14% (9/65), which was lower than a previous necropsy study[30] in which 35.2% of the cats had at least one CU. In that study[30] none of the kidneys had gross evidence of hydronephrosis or obstruction and the previous kidney values were not known, thus the clinical relevance of the CU was unknown. The difference in frequencies between the previous study (35.2%) and the present study (14%) could be a result of sample size (65 versus 301), selection bias (referral hospital versus shelter), or geographic location. In the previous study[30] there was no sex predilection for the presence of a CU. This was also seen in the circumcaval obstructed ureters (Group 1) in this study. In the present necropsy group (Group 3), the ratio of males: females was 2 : 1 and in humans it is also found that CUs are more commonly found in males (3 : 1).[10,32,33] The reason for higher number of males with CUs in the necropsy group could not be determined.

The majority of the non-obstructed (89%; Group 3) and obstructed (80%; Group 1) CUs were on the right side, which is similar to that previously reported in cats and humans.[10,30] The cause of a ureteral obstruction with an associated CU is speculated to either be from compression of the ureter by the vena cava,[34] kinking of the ureter due to the tortuous course it takes around the vena cava, a localized fibrotic reaction that occurs within the ureter, a periureteral venous ring that can occur with gonadal and lumbar veins,[35,36] and the development of a ureteral stricture that occurs during embryological development as the ureteric bud is being formed, and concurrently compressed by the vein.[37,38] In humans, marked hydronephrosis is seen in 50% of patients with Type I CUs, which ultimately develop obstructive disease.[39] In this study 71% of patients with CUs (Groups 1 and 3) were documented to be obstructed. Furthermore, 40% of the circumcaval obstructed ureters in this study were associated with either a presumptive stricture alone or a stricture and stone (Table 3). In the recent necropsy study[30] none of the CUs were associated with evidence (eg, hydronephrosis/hydroureter) of a ureteral obstruction, however patency of the ureter was not determined and biopsies of the ureters were not taken, therefore the existence of a non-obstructive stricture cannot fully be excluded from that population.

Previous studies on ureteral obstructions in cats[21,22,25,26,31] report nonspecific clinical signs like reduced appetite, vomiting, lethargy, and weight loss, which was similar to that reported in this study, regardless of the presence or absence of a CU. Furthermore, clinical signs were not able to distinguish between a circumcaval and non-circumcaval obstructed ureter(s).

In the present study, the majority of cats had renal azotemia despite a large number of the ureteral obstructions being unilateral, suggesting concurrent contralateral renal impairment. The existence of azotemia with a low urine specific gravity, in a unilaterally obstructed animal, is consistent with previous reports addressing feline ureteral obstruction(s).[21,25,26,31] Furthermore, chronic kidney disease is common (75–97%) in cats with ureteral obstructions[21,22,25–27,31,40] and in this study 73% of cats in Group 1 and 45% of cats in Group 2 were historically diagnosed with chronic kidney disease. The presence of chronic kidney disease and azotemia in ureterally obstructed patients highlights the need for kidney sparing treatment(s) and expedited decompression of these obstructions in order to preserve as much renal function as possible.

Ultrasonographic imaging has increased our ability to detect changes in the size of the ureter and renal pelvis, aiding in the diagnosis of a ureteral obstruction. In this study there was no significant difference in the size of the dilated renal pelvis or ureter based on ultrasound measurements between circumcaval and non-circumcaval ureteral obstructions.

A pre-surgical diagnosis of a CU was uncommon and a definitive diagnosis required surgical exploration. In people, an intravenous urogram or CT angiogram can be used to diagnose CUs based on the "fish-hook" shape of the tortous ureter,[13,41] avoiding the need for an exploratory. The difference in this approach in humans and cats is that all causes of ureteral obstructions in humans are typically treated endourologically with cystoscopy, ureteroscopy and/or fluoroscopy. If a CU is diagnosed then this is typically treated laparoscopically with a ureteral resection and anastomosis over a ureteral stent.[13] In feline medicine, the feline ureter can rarely be treated endoscopically alone, and requires surgical assistance, therefore there is no need for pre-operative imaging modalities like CT or intravenous urogram. Placement of a double pigtail stent or a SUB device utilizes an antegrade pyelogram for renal pelvis and ureteral access, this is helpful in making the diagnosis of the "fish-hook" ureter and diagnosing a definitive cause of obstruction (Fig 2).

Previous studies[22,26,31] have documented 62–85% of the cases of ureteral obstructions had concurrent nephroliths. In this study, 64% of the CU obstructed kidneys had concurrent nephrolithiasis, which may predispose the ureter to a subsequent ureteral obstruction in the future. In one study,[42] 40% of patients treated with traditional ureteral surgery (eg, ureteral implantation) or medical therapy alone, developed another ureteral obstruction(s) at a median of 1 year. Having alternatives to traditional ureteral surgery is important especially with a circumcaval ureteral obstruction(s), where strictures and a proximal location of the obstruction are common, making them less amendable traditional ureteral surgeries.

In this study there was a lower percentage (20%) of re-obstructions documented compared to the previous study (40%).[20,21,23] This data should be carefully compared when reviewing traditional literature, as those studies focused only ureterolithiasis,[21,22,27,42] where in this study 40% of the ureters in the circumcaval group (21% of all ureters) had a presumptive ureteral stricture, making traditional surgical options more difficult.

A recent paper[25] was the first to describe a small series of cats with ureteral strictures. In that study[25] the cats were treated with either traditional surgery, ureteral stent or a SUB device. In that study[25] 50% of patients that had a stent placed required re-stenting or the use of a SUB device due to re-obstruction of the ureter at the site of the ureteral stricture. In the present study, obstructed ureters treated with a double pig-

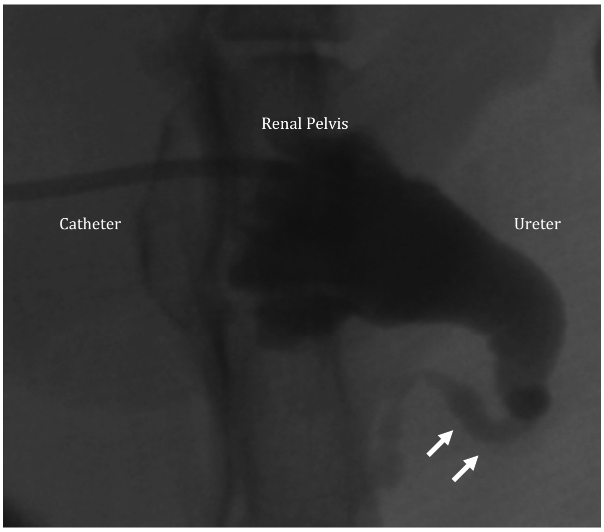

Fig 2. Fluoroscopic image of an antegrade pyelogram showing characteristic "fish-hook" ureter (arrows) associated with a circumcaval ureter.

tail stent were significantly more likely to re-obstruct when compared to those treated with a SUB device. When a ureteral stricture is present, the ureter will not passively dilate at the stricture site following stent placement. Without passive dilation these patients are at risk for re-obstruction at the site of the stricture since crystalline debris will occlude the lumen of the stent over time. It is the passive dilation that is suspected to maintain ureteral patency long-term. Based on the results of this study, feline ureteral obstructions, especially those secondary to a ureteral stricture, are recommended to be treated with a SUB device.

Previous studies[22,26,31] have demonstrated that 10–30% of cats with ureteral obstructions had a documented urinary tract infection. In this study 9% (Group 1) to 21% (Group 2) of the patients had evidence of a urinary tract infection at presentation. The presence of a ureteral obstruction in people has been shown to impair entry of antibiotics into the collecting system necessitating renal decompression.[41] In addition, the placement of a device (stent or SUB) in an infected animal did not affect the length of hospitalization, survival to discharge, creatinine at discharge, or creatinine at 3 months. All patients were discharged on antibiotics following device (stent or SUB) implantation for a minimum of 2 weeks. None of the cats were on long-term antibiotics. A recent study[43] showed that orally administered antibiotics excreted in the urine can reduce the risk of biofilm formation and persistent infection for ureteral devices. Chronic infection was also not an issue in the long-term for any cat in this study.

The peri-operative mortality rates for traditional surgical treatment (eg, ureterotomy) is reported to be 21% (range from 18 to 30%).[27,42] In this study the perioperative mortality was 7.8% (10/128), none of which was associated with complications of surgery or the ureteral obstruction. Only 3% of cats were euthanized prior to discharge for failure of renal function improvement.

There were several limitations to this study. The retrospective nature and small sample size make comparisons between the 3 groups difficult. Additionally, many patients had both a presumptive ureteral stricture and multiple stones, but a stricture could not be definitively determined without histopathology. Because removal of a ureteral segment was not necessary or recommended, the diagnosis was made based on contrast ureterography, ureteral palpation, and evidence of an obstructive lesion during surgical exploration unassociated with a ureteral stone at the obstructed site. Although all the ureters in the necropsy group (Group 3) were considered patent based on the gross lack of hydroureter or hydronephrosis, biopsies of the ureters were not taken in order to completely rule out strictures and/or fibrosis within the ureter. One other limitations of this study is that only 1 ureter was treated medically that was included in this study. This is because this cat had a surgical exploration for treatment of an obstructed ureter, and at the time of SUB device placement the contralateral kidney that had been obstructed, was no longer obstructed, so surgical treatment was not performed on that side. In the patients where medical management was successful, a confirmed CU diagnosis was unlikely (no surgical exploration) and therefore could have been missed. For the necropsy group there may have been some selection bias since the AMC sees a lot of cats with CKD, and the necropsy cases may overestimation cats with CUs and/or CKD.

In conclusion, this study showed that ureterally obstructed cats with CUs have a similar outcome to those without a CU when treated with either a double pigtail stent and/or a SUB device. Presenting clinical signs, history, biochemical data, and ultrasound findings do not typically distinguish CUs from non-CUs. Finally, the most common long-term complication with either device is re-obstruction, and is more common with a double pigtail ureteral stent than it is with a SUB device, especially in the face of a ureteral stricture.

Footnotes

[a] Infiniti Medical LLC, Menlo, CA
[b] Subcutaneous Ureteral Bypass System (SUB), Norfork Vet Products Inc, Skokie, IL
[c] Stata release 12, 1996-2013, StataCorp LP, College Station, TX
[d] Includes 5 non circumcaval obstructions from Group 1

Acknowledgment

Conflict of Interest Declaration: Drs Berent and Weisse are consultants for Norfork Vet and Infiniti Medical.

Off-label Antimicrobial Declaration: The authors declare no off-label use of antimicrobials.

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