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Complications and survival after subcutaneous ureteral bypass device placement in 24 cats: a retrospective study (2016–2019)

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Abstract

Objectives The aim of this study was to document survival, complications and risk factors for the development of complications and mortality prior to discharge after placement of a subcutaneous ureteral bypass (SUB) device in cats.

Methods The medical records of cats with SUB placement between January 2016 and August 2019 were retrospectively analysed. The development of complications (overall, intraoperative, perioperative, short- and long-term complications) and risk factors for mortality prior to discharge were statistically assessed with univariate binary logistic regression. All variables with a P value ≤ 0.10 in the univariate analysis were assessed in a multivariate model. Variables were significant if $P < 0.05$.

Results Twenty-four cats were included; 12 (50.0%) received a unilateral SUB, 11 (45.8%) a bilateral nephrostomy tube with single cystostomy catheter and the remaining cat (4.2%) two unilateral SUBs. Nearly 80% of the cats developed complications, ranging from mild to fatal, including (partial) SUB obstruction (33.3% of complications), lower urinary tract infection (20.8%), pyelonephritis (20.8%) and sterile cystitis (12.5%). Five cats (20.8%) died prior to discharge. Six cats (25.0%) underwent revision surgery. The overall median survival time (MST) was 274 days (range 1–311 days). Complications were most common in the long-term period (14/16 cats), followed by the short-term (9/18 cats), perioperative (10/23 cats) and intraoperative (4/24 cats) periods. Older cats had an increased risk for developing perioperative complications ($P = 0.045$) and were less likely to survive to discharge ($P = 0.033$). An increased haematocrit at presentation was a risk factor for the occurrence of short-term complications ($P = 0.03$).

Conclusions and relevance Although complications similar to those previously described were observed, the complication rate was higher and the MST shorter than previously reported in cats undergoing SUB placement. Despite good short-term survival, the development of complications may necessitate regular and intensive control visits. Owners that consider SUB placement should be informed that follow-up can be strenuous and expensive.

Keywords: Ureteral obstruction; subcutaneous ureteral bypass; complications; risk factors; survival

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Introduction

The most common cause of feline ureteral obstruction is ureterolithiasis, with >90% of calculi consisting of calcium oxalate.[1,2] Less common causes are congenital ureteral strictures, mucus plugs, solidified blood calculi, fibrosis, inflammation, trauma, iatrogenic ligation and neoplasia.[1,3–5] Ureteral obstructions can be life-threatening owing to the development of secondary acute kidney injury (AKI).[6] Early treatment results in renal decompression and improvement of overall renal function.

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Treatment consists of medical management, effective in merely 13% of cases and therefore it is often combined with surgical relief of obstruction.[1] Traditional surgical treatment includes ureterotomy, end-to-side neoureterocystostomy and ureteronephrectomy.[1,7,8] Although surgery is more effective than conservative treatment, mortality rates of up to 39% are reported.[1,7] These techniques are also associated with a high rate (31%) of major complications, including uroabdomen, persistent ureteral obstruction, postoperative ureteral swelling and stricture formation.[1,7]

Recently, alternative techniques have emerged; namely, double pigtail ureteral stents and subcutaneous ureteral bypass (SUB) devices. In contrast to traditional techniques, these devices do not remove the obstruction, but bypass it.[9,10] Both techniques have gained popularity because of their less invasive nature and lower perioperative mortality rate (7.6–15.0% for ureteral stents and 6.0–15.4% for SUBs).[9–14] The main disadvantage of these devices is the introduction of implants, which is associated with complications, including haematuria, sterile cystitis, urinary tract infection (UTI) and device obstruction.[10,13–17] Reported median survival times (MST) in cats after stent and SUB placement are 420–498 and 820–827 days, respectively.[9–11,15,17] Ureteral stenting is considered technically more difficult than SUB placement.[18,19]

This study aimed to document the complications and survival after SUB placement and to identify risk factors for complications and mortality prior to discharge.

Materials and methods

The medical records of cats that underwent SUB placement between January 2016 and August 2019 were retrospectively reviewed.

Data collection

Preoperative data were collected from the hospital files. Preoperative medical management was attempted in all cats, which consisted of intravenous fluid therapy, analgesia and vasopressors, if necessary. Hyperkalaemia was treated with human insulin, glucose and calcium gluconate as required. The SUB device was placed according to the manufacturer's instructions, although the pigtail of the nephrostomy catheter was coiled within the pelvis and not the proximal ureter even if the renal pelvis was smaller than 8 mm. Nephrostomy catheters were placed with imaging guidance (fluoroscopy or ultrasound [US]) or blindly, following the identical method as described by Livet et al[14] and Berent et al.[20] Based on the technique of Van Klaveren et al,[21] the nephrostomy catheter was inserted under US guidance in the renal pelvis and, after confirmation of its intrapelvic position, the pigtail was coiled. Subsequently, by scanning in different planes, correct pigtail formation was assessed. As only one cat had a SUB placed under fluoroscopic guidance, we used the term 'imaging', which includes US- and fluoroscopic-guided placement. Urine samples were collected from the renal pelvis for culture and sensitivity. Straight cystostomy catheters were shortened depending on the surgeon; the most recent cats had a locking-loop pigtail cystostomy catheter. During anaesthesia, hypotension was defined as mean arterial pressure <70 mmHg, low oxygen saturation as SpO_2 <90% and hypocapnia as end-tidal CO_2 <30 mmHg, all if present longer than 5 mins.[22–24] For cats that had undergone previous (traditional) surgery for ureteral obstruction, only the data at the time of the SUB surgery were included.

Postoperatively, plain orthogonal abdominal radiographs were taken in cats that had their SUBs placed with US guidance or blindly to identify device kinking. Postoperative management during hospitalisation consisted of monitoring hydration status, urinary output and serum concentrations of creatinine and electrolytes. Analgesia and antimicrobial therapy were tailored to the individual patient. Length of hospitalisation stay was recorded.

If cats were re-presented for follow-up visits, SUBs were flushed using sterile saline under US guidance. Referring veterinarians were contacted to determine survival time and cause of death of cats that were lost to follow-up.

Complications were classified as intraoperative (from anaesthetic induction to <8 h postoperatively), perioperative (from 8 h to 7 days postoperatively), short term (from 8 to 30 days postoperatively) or long term (>30 days postoperatively), as suggested before.[10]

For the purpose of this study, all postoperative radiographs were reassessed with special attention paid to the placement of both catheters and the straight cystostomy catheter length. Suboptimal placement was defined as an incomplete pigtail formation for nephrostomy catheters or any location other than the bladder apex for the cystostomy catheters.

Statistical analysis

Statistical analysis was performed using SPSS Statistics 25 (IBM). Data were tested for normality using a Shapiro–Wilk test; provided as mean ± standard deviation if normally distributed and as median (range) if not. Univariate binary logistic regression was used to identify potential risk factors for mortality prior to discharge and for complication development (overall, intraoperative, perioperative, short- and long-term), using each potential predictor variable. Subsequently, multivariate binary logistic regression models were performed using all variables with a P value ⩽0.10 in the univariate analysis. First, forward regression was performed. Afterwards, excluded variables were reassessed by entering them individually into the model. Variables were retained if P <0.05. Overall survival time was documented with the Kaplan–Meier

curve and MST with its corresponding 95% confidence interval (CI) was calculated. For cats that were still alive, time to last follow-up was used to calculate survival time and the case was censored.

Results

Signalment, history and clinical findings

Twenty-four cats met the inclusion criteria. The most common breeds were domestic shorthair (n = 8), British Shorthair (n = 5) and Ragdoll (n = 5). Median age was 71.5 months (range 28–164 months) and mean ± SD body weight was 3.5 ± 0.1 kg (Table 1). Clinical signs were hyporexia (n = 19), lethargy and vomiting (n = 10 each), diarrhoea and weight loss (n = 7 each), polyuria/polydipsia (n = 3), stranguria and pollakiuria (n = 2 each), haematuria and dysuria (n = 1 each). The median duration of clinical signs was 6 days (range 2–180 days; n = 23). Five cats had at least two previous episodes of ureteral obstruction; two underwent a ureterotomy and the remainder were treated conservatively. Rectal temperature ranged from 36.7°C to 40.4°C (n = 19); eight cats were hypothermic. Six cats were clinically dehydrated. Auscultation revealed a heart murmur in six cats and arrhythmia in one additional cat. In 4/10 cats that underwent echocardiography, heart disease was diagnosed: two had hypertrophic cardiomyopathy, one dynamic left ventricular outflow tract obstruction secondary to systolic anterior motion and one had mild mitral-, tricuspid- and pulmonary valve insufficiency.

Clinicopathological findings

Preoperative clinicopathological findings are given in Table 2. Five cats had crystalluria; two with amorphous crystals, one calcium oxalate, one struvite and another had both struvite and calcium oxalate. Cystocentesis was performed in 17 cats and urine cultures were positive in seven (41.2%) (Table 3).

Preoperative diagnostic imaging

Abdominal US was performed in all cats, representing in total 34 affected ureters. Twenty-three cats (95.8%) had obstructive ureterolithiasis, which was unilateral in 14 cats and bilateral in nine. One cat (4.2%) had a bilateral ureteral obstruction owing to a bladder trigone neoplasia. The majority of single ureteroliths were located either in the proximal (38.2%) or distal ureter (32.4%), whereas the remainder were in the mid-ureter (14.7%). Multiple uroliths were present in 3/34 ureters (8.8%). In total, 18/48 kidneys contained nephroliths. Nineteen cats (79.2%) had bilateral and five (20.8%) unilateral pyelectasia, with a median pelvic diameter of 7 mm (range 1–30 mm; n = 38). Sixteen cats (66.7%) had ultrasonographic signs compatible with chronic kidney disease (CKD); five demonstrated big kidney–small kidney syndrome.[25,26]

Intra-, peri- and postoperative data

Preoperatively, antimicrobial therapy consisted of intravenous marbofloxacin or cefazolin (n = 10 each). Four cats did not receive any antimicrobials.

In 17 cats (70.8%) a straight cystostomy catheter was placed and in seven (29.2%) a locking-loop pigtail catheter (Table 1). Eleven cats received a bilateral SUB with a single cystostomy catheter (PantsPort; Norfolk Vet Products). In 10 cats the SUB was placed blindly, in nine with US guidance and in one fluoroscopically. During anaesthesia, 12/23 cats had at least one period of hypotension, 1/21 had a low oxygen saturation and 1/21 hypocapnia. Mean duration of anaesthesia and surgery was 137.8 ± 5.1 mins and 100.0 ± 4.4 mins, respectively. Immediate postoperative radiographs were taken in all but two cats. In one cat a kink in the SUB was observed (Figure 1); this cat underwent revision surgery 2 days later because of persistent azotaemia. Postoperatively, marbofloxacin was administered in 17 cats, potentiated amoxicillin in three, cefazolin in one and one cat received marbofloxacin combined with potentiated amoxicillin. In two cats the preoperative antimicrobial therapy was discontinued postoperatively.

Postoperatively (<24 h), mean serum creatinine was 596 ± 69 µmol/l (n = 22) and potassium 5.3 ± 0.7 mmol/l (n = 21). Fifteen of 18 cats with documented urinary output had post-obstructive diuresis; the mean urine output was 3.8 ± 0.4 ml/kg/h. Mean hospitalisation time was 9.2 ± 0.8 days (n = 19). Mean serum creatinine concentration at discharge was 237 ± 14 µmol/l (n = 18).

Complications

Overall, 19/24 cats (79.2%) developed complications (Table 1). In 4/24 cats (16.7%) intraoperative complications occurred, including ischaemic encephalopathy, fluid overload and persistent hyperkalaemia.

Ten of 23 cats (43.5%) developed perioperative complications, most commonly device obstruction and UTI. Short-term complications were recorded for 9/18 cats (50.0%) and 14/16 cats (87.5%) had long-term complications; most frequently SUB obstruction, UTI, sterile cystitis and pyelonephritis.

The most common overall complications were SUB obstruction (n = 8/24 [33.3%]), lower UTI and pyelonephritis (n = 5/24 [20.8%] each) and sterile cystitis (n = 3/24 [12.5%]). Three of 24 cats (12.5%) had kinking of the SUB device. In two, the SUB was placed blindly; information regarding SUB placement (with or without imaging guidance) in the third cat was lacking.

Five of 24 cats (20.8%) presented with a postoperative UTI; two perioperative, one in the short-term and two in the long-term period. Isolated bacteria were *Escherichia coli* (60.0%) and *Klebsiella pneumoniae* (40.0%). One isolated *E coli* strain was sensitive to multiple antimicrobials,

Table 1 Demographic data and summary of intraoperative data and complications of 24 cats undergoing surgery for subcutaneous ureteral bypass (SUB) placement for (partial) ureteral obstruction

Breed	Age (months)	Sex	Indication	SUB	Intraoperative imaging modality	Intraoperative complications	Perioperative complications	Short-term complications	Long-term complications
Ragdoll	38	FS	UL	Uni	Fluoroscopy	None	AKI	None	Obstruction CU
DSH	159	MC	UL	Uni (2×)	Blind	None	Obstruction CU	Oral ulceration	AKI
Ragdoll	62	FS	UL	Uni	Blind	None	None	Sterile cystitis	Pyelonephritis
Ragdoll	79	FS	UL	Bi	Blind	None	Obstruction SUB	Obstruction SUB UTI Pyelonephritis	–
Birman	102	MC	UL	Uni	Blind	None	None	None	Obstruction SUB
DSH	37	MC	UL	Uni	Blind	None	None	None	None
Bengal	69	MC	UL	Bi	Blind	None	Obstruction SUB	Pyelonephritis	Obstruction SUB
DLH	43	FS	UL	Bi	–	None	None	Sterile cystitis	Pyelonephritis Sterile cystitis UTI
BSH	41	MC	UL	Bi	–	IE	Obstruction SUB	–	–
DSH	37	MC	UL	Uni	Blind	None	None	None	Obstruction SUB Obstruction CU
DSH	49	FS	UL	Uni	–	None	None	None	Obstruction SUB Hypercalcaemia
Persian	74	MC	UL	Uni	US	Fluid overload	Fluid overload aspiration pneumonia Non-regenerative anaemia UTI	UTI Pyelonephritis	UTI Pyelonephritis
Birman	66	FS	UL	Bi	US	None	None	Haematuria	Uroabdomen
BSH	28	MC	UL	Bi	–	None	None	None	None
ScF	76	FS	UL	Uni	Blind	None	None	–	–
BSH	120	MC	N	Bi	US	Obstruction SUB	Hypothermia Hypotension	–	–
Ragdoll	164	MC	UL	Bi	US	PHK		–	–
BSH	44	MC	UL	Uni	US	None	None	None	None
DSH	50	FS	UL	Uni	Blind	None	None	Obstruction SUB	Obstruction SUB
DSH	94	FS	UL	Bi	US	None	None	None	UTI
DSH	96	FS	UL	Bi	US	None	None	None	AUS Proteinuria
Ragdoll	79	MC	UL	Uni	Blind	None	UTI	UTI	UTI Sterile cystitis
DSH	120	FS	UL	Bi	US	None	Seizures	–	–
BSH	152	FS	UL	Uni	US	None	Seizures Fluid overload	–	–

FS = female spayed; UL = ureterolithiasis; Uni = unilateral; AKI = acute kidney injury; CU = contralateral ureter; DSH = domestic shorthair; MC = male castrated; Bi = bilateral; UTI = urinary tract infection; DLH = domestic longhair; BSH = British Shorthair; IE = ischaemic encephalopathy; US = ultrasound; ScF = Scottish Fold; N = neoplasia; PHK = persistent hyperkalaemia; AUS = active urine sediment

Table 2 Important clinicopathological values of blood analysis and urinalysis in cats prior to subcutaneous ureteral bypass placement

Variable	n	Value	RI
Haematocrit (%)	23	27.8 ± 1.3	30.3–52.3
Creatinine (µmol/l)	24	1010 ± 138	71–212
Sodium (mmol/l)	24	158.6 ± 1.2	150.0–165.0
Potassium (mmol/l)	24	4.8 (3.6–10.5)	3.5–5.8
Total calcium (mmol/l)	12	2.40 ± 0.10	1.95–2.83
Ionised calcium (mmol/l)	3	1.63 (1.33–1.79)	1.13–1.38
USG (prior to fluid therapy)	11	1.015	1.009–1.029
Urine pH	10	6.0 (5.0–7.0)	6.0–7.0
Pyuria	8/14	–	<23 leukocytes/µl

Data are mean ± SD or median (range)
RI = reference interval; USG = urine specific gravity

Table 3 Sensitivity panels of cats with a lower urinary tract infection prior to and/or after placement of a subcutaneous ureteral bypass

		Penicillin		CS			CP	AG	TC	SA	(F)Q	Ph	ML/LM	NF	Fo
		P	PP	First generation	Third generation	Fourth generation									
EC	Pre	S	S	S	S	–	–	S	S	S	S	S	–	–	–
EC	Pre	S	–	S	–	–	–	S	–	S	S	–	–	S	–
SC	Pre	S	–	–	–	–	–	–	–	S	S	–	S	–	–
EC*	Pre	S	S	S	–	–	–	S	–	S	S	–	–	S	–
	Po (after MF)	S	–	S	–	–	–	S	–	S	S	–	–	S	–
EC	Po	R	S	S	–	–	–	S	–	S	R	–	–	S	–
	Po (after CZ and PP)	R	R	R	S	S	–	S	R	S	R	R	–	S	–
EC	Pre	R	R	R	R	–	I	R	R	R	R	–	–	S	S
	Po (1 month after MF)	R	R	R	R	–	I	R	R	R	R	–	–	S	–
EC/	EC (pre)	S	S	S	–	–	–	S	–	S	S	–	–	S	–
KP	KP (po) (6 weeks po after MF)	–	R	R	R	–	S	R	–	R	R	–	–	R	–
KP	Pre	R	R	R	R	–	–	S	R	S	R	–	–	S	–
	Po (1 week po after MF)	–	R	R	R	–	–	S	R	S	R	–	–	R	–

*The only one of the five cats with a urinary tract infection after placement of a subcutaneous ureteral bypass, which resolved after a 6-week marbofloxacin course
CS = cephalosporins; P = penicillin; PP = potentiated penicillin; CP = carbapenems; AG = aminoglycosides; TC = tetracyclines; SA = sulphonamides; (F)Q = (fluoro)quinolones; Ph = phenicols; ML = macrolides; LM = lincomycin; NF = nitrofurantoin; Fo = fosfomycin; EC = *Escherichia coli*; Pre = preoperative; S = susceptible; SC = *Staphylococcus capitis*; Po = postoperative; MF = marbofloxacin; R = resistant; CZ = cefazolin; I = intermediate; KP = *Klebsiella pneumoniae*

whereas the other two strains and both *K pneumoniae* were multidrug resistant. In 1/5 cats the UTI resolved with a 6-week marbofloxacin course. The infection persisted in all other cats, despite several (appropriate) antimicrobial therapies (Table 3).

Seven revision surgeries were performed in six cats; median time between initial and revision surgery was 85 days (range 2–357 days). Two cats had a radiographically confirmed kink in the nephrostomy catheter. The clinical recovery was unsuccessful and they underwent revision surgery after 2 and 5 days, respectively. One cat developed a cystostomy catheter kink after 27 days and the device was repositioned. Another cat presented 85 days postoperatively with a uroabdomen due to a migrated (straight) cystostomy catheter. In two cats, a unilateral nephrostomy catheter was replaced after intraluminal obstruction (encrustation) 188 and 357 days after the initial surgery; one of these was the cat that had revision

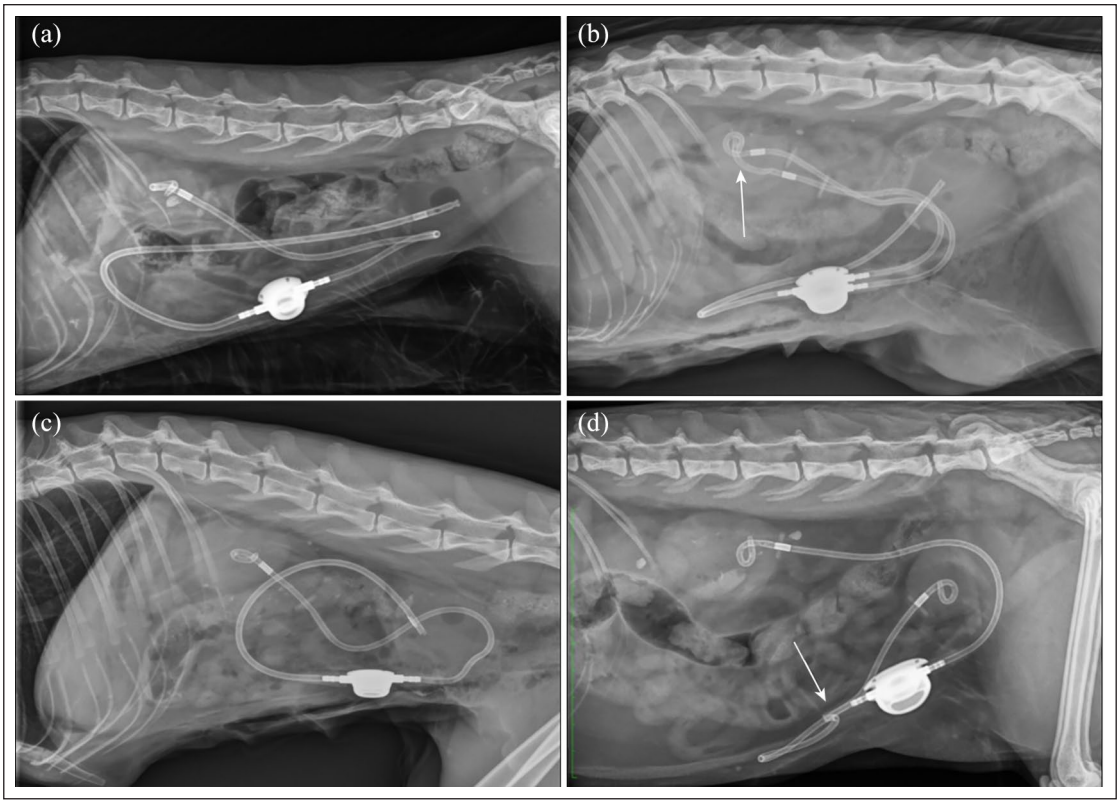

Figure 1 Postoperative radiographs after placement of a subcutaneous ureteral bypass (SUB) device. (a) Correctly placed unilateral SUB device with a multi-fenestrated straight cystostomy catheter. The pigtail in the renal pelvis is well deployed. (b) The nephrostomy catheter did not form a correct pigtail (arrow). (c) The cystostomy catheter was not placed in the apex of the bladder, but too dorsally. (d) Presence of a kink (arrow) in the cystostomy catheter

surgery 5 days after initial SUB placement. One cat with ongoing sterile cystitis underwent revision surgery 204 days postoperatively; the (straight) cystostomy catheter was shortened after which the cystitis resolved. One cat with a unilateral SUB developed an obstruction of the contralateral ureter prior to discharge and the original SUB was replaced by a bilateral device (PantsPort; Norfolk Vet Products) 5 days after the initial surgery.

Necropsy was performed in one cat that developed neurological signs and died after a cardiopulmonary arrest (CPA). The pigtail of the nephrostomy catheter was incompletely deployed within the renal pelvis, resulting in a subcapsular renal haematoma (Figure 2). Subsequently, all postoperative radiographs (n = 22) were reassessed, demonstrating suboptimal placement of eight nephrostomy and one straight cystostomy catheter.

Follow-up data

Three cats were lost to follow-up after 61, 95 and 135 days, respectively. Three months after SUB placement, follow-up data were available for 14 cats; 8/14 had CKD International Renal Interest Society stage 2, five stage 3 and one stage 1.

Survival

Five cats (20.8%) either died (n = 2, one <8 h postoperatively) or were euthanased (n = 3) prior to discharge. One non-survivor had persistent hyperkalaemia (10.5 mmol/l at presentation) and remained comatose postoperatively; euthanasia was requested 1 day postoperatively. Three cats developed neurological signs, followed by CPA in two within <48 h; the third cat was euthanased 5 days postoperatively. One of these three cats had severe hypertrophic cardiomyopathy and one severe hyperkalaemia (8.4 mmol/l) at presentation. Another non-survivor, a cat diagnosed with trigonal high-grade B lymphoma, suffered an episode of hyperkalaemia that resolved by SUB flushing but developed refractory hypotension of unknown cause and was euthanased 3 days postoperatively.

Eight cats (33.3%) died or were euthanased after discharge because of obstructed contralateral ureter (n = 2; (124 and 234 days postoperatively, respectively), SUB obstruction (311 days postoperatively), lack of postoperative clinical improvement (13 days postoperatively), AKI, progressive CKD and persistent UTI (30 days postoperatively), pleural effusion and unknown cause (n = 1 each). Seventeen cats were still alive >30 days postoperatively;

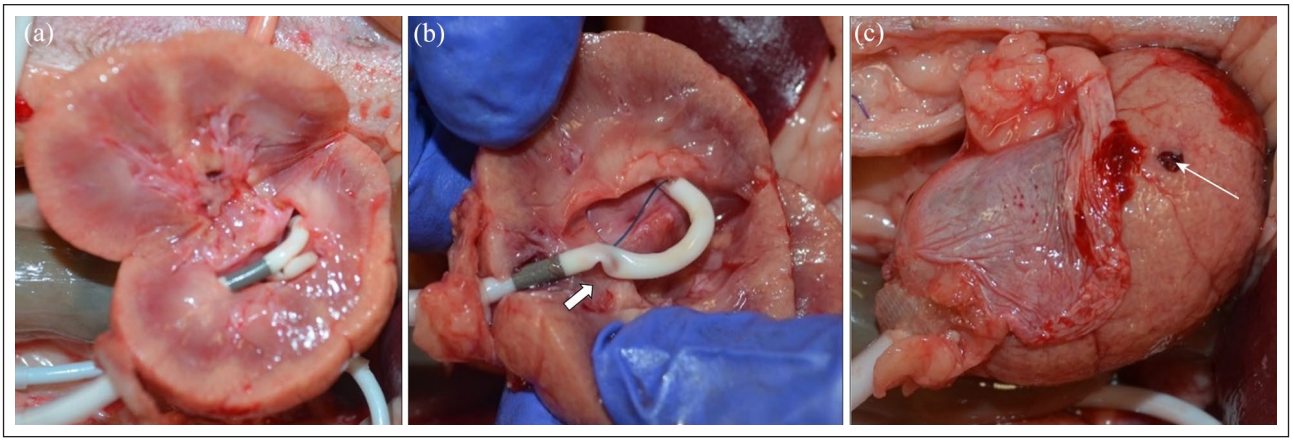

Figure 2 Photographs taking during the post-mortem examination of a cat that died after a cardiopulmonary arrest 4 days after bilateral subcutaneous ureteral bypass (SUB) placement. (a) Correctly placed right-sided nephrostomy catheter with a nicely formed pigtail. (b) Incomplete pigtail of the nephrostomy catheter with the presence of a kink (arrow) in the nephrostomy catheter. (c) Subcapsular renal haematoma (arrow) without perforation of the renal capsule secondary to an incorrectly placed nephrostomy catheter

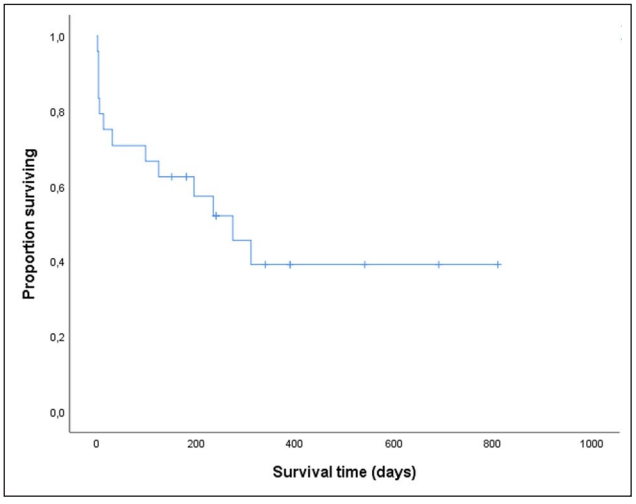

Figure 3 Kaplan–Meier survival curve for all cats that underwent subcutaneous ureteral bypass placement. Vertical tick marks represent censored observations

median long-term follow-up was 240 days (range 61–810 days). The overall MST was 274 days (range 1–311 days; 95% CI 135–413) (Figure 3).

The univariate binary logistic regression test identified potential risk factors, including age, temperature and the presence of pyuria, heart disease and UTI at presentation, preoperative blood values (haematocrit, potassium, total calcium, creatinine), episodes of obstruction prior to surgery, duration of clinical signs, US findings (signs of preoperative CKD, pelvic dilatation at the side of SUB placement), preoperative antimicrobial treatment, intraoperative hypotension, duration of anaesthesia, surgical technique (imaging guided [fluoroscopic or US guided] vs blind), suboptimal SUB placement perceived on retrospectively assessed radiographs, need for revision surgery prior to discharge, postoperative urine production, creatinine levels, and ratio of preoperative and postoperative creatinine concentration (see supplementary material). Risk factors used in the multivariate analysis included age, body weight, preoperative haematocrit and potassium, ratio of preoperative and postoperative creatinine, and urine production 24 h postoperatively. Multivariate analysis indicated that older cats had a higher risk of developing perioperative complications and were less likely to survive to discharge (Table 4). Cats presented with an increased haematocrit had significantly higher odds to develop complications in the short-term period (Table 4).

Table 4 Risk factors for survival to discharge and development of complications after multivariate analysis associated with placement of a subcutaneous ureteral bypass device in cats

	Variable	*P* value	OR	95% CI
Perioperative complications	Age (months)	0.045	1.049	1.001–1.099
Survival to discharge	Age (months)	0.033	0.947	0.901–0.996
Short-term complications	Preoperative Hct (%)	0.03	1.04	1.004–1.078

OR = odds ratio; CI = confidence interval; Hct = haematocrit

Discussion

This study confirmed that SUB placement is a valuable therapeutic approach in cats with ureteral obstruction, as most cats showed immediate postoperative clinical and clinicopathological improvement. Nevertheless, overall complications occurred in 79.2% of the cats and almost 90% of the cats surviving long-term experienced complications.

Perioperative and short-term complication rates were similar to those reported in previous studies (42.8% and 14.2–63.6%, respectively).[13,14] Although complications occurred frequently, these were mainly minor, which is in contrast with the findings of another recent study, where major complications were more commonly reported.[17]

Data on overall and long-term complications after SUB placement are scarcely reported in the literature and therefore comparisons are difficult; nevertheless, they appear lower than what has been observed in the current study.[10,13,14,17] A hypothesis for these high long-term complication rates could be suboptimal SUB placement, which could be due to the surgical technique used (with or without imaging guidance). Although fluoroscopic-guided placement is considered the gold standard,[14,17,20,21,27] SUBs were mainly placed by US guidance or blindly at our institution. The main reason for this is the lack of appropriate materials. Despite the lack of fluoroscopy, similar complications were observed as those described after fluoroscopic-guided placement.[10,17] This could be a type II error as it aligns with the results of a previous study, reporting successful blind SUB placement.[14] Also, US-guided placement has been proposed as a viable alternative to fluoroscopic-guided placement and seems to be the most practical approach.[21,27]

Plain postoperative radiographs were used in our study and therefore subtle urine leakage could not be excluded, and a correct positioning of the pigtail in the renal pelvis could not be confirmed.[17] This is mainly important for cats that had the SUB placed blindly, as intraoperative US guidance enabled confirmation of the correct intrarenal positioning of the catheter. Fluoroscopic guidance has the advantage over US guidance that it might detect leakage and kinking of the nephrostomy catheter more accurately, allowing immediate intraoperative correction. It is recommended to take orthogonal radiographs immediately postoperatively in cats that have a SUB placed blindly or with US guidance to detect kinking of the catheters. The number of cats in the present study that had kinks in their catheters (12.5%) was higher than that described by Kulendra et al (5%),[17] who attributed the kinking to the length of tubing in the subcutaneous space. Prospective studies are needed to investigate the optimal length of tubing to avoid kinking of catheters postoperatively. The addition of contrast radiographs can help to detect the presence of possible leakage.

Necropsy in one cat demonstrated an incompletely formed pigtail, despite intraoperative US confirmation of its presence in the renal pelvis. Most likely, the nephrostomy catheter was advanced too slowly, leading to a rapid decrease in pelvic cavity size by urine drainage, causing the tip of the catheter to get stuck in the renal cortex, preventing the pigtail from forming completely. Suboptimal SUB placement based on the reassessed postoperative plain radiographs could not be identified as a risk factor for developing complications in the small number of cases in present study. Nevertheless, suboptimally placed nephrostomy catheters can damage the renal parenchyma, potentially resulting in (accelerated) progression of CKD. Uroperitoneum might develop after perforation of the renal capsule. Kinking of the nephrostomy catheter can result in fewer holes (stuck within renal parenchyma or non-functional owing to kinking) available to drain urine, with possible insufficient urine drainage, resulting in persistent hydronephrosis, azotaemia and an increased risk of device obstruction.[17] Therefore, urine stasis can predispose to pyelonephritis.[14,28–32]

The incomplete pigtail formation was also observed by others in a very recent study; despite intraoperative fluoroscopy, penetration of the kidney with subcapsular leakage was noted postoperatively. In the same study, an incomplete deployed pigtail led to obstruction of the nephrostomy catheter in one cat, leading to euthanasia. It was therefore recommended that the the nephrostomy catheter be replaced immediately if kinking is observed.[17]

A previous study in humans reported that even short durations of hypotension are associated with AKI and myocardial injury, which can lead to a poor patient outcome.[33] Although in the present study 12/23 cats had hypotension intraoperatively, this could not be identified as a risk factor. Intraoperative hypocapnia or hypoxemia can lead to poorer outcomes.[34,35] This aligns with the present findings, as cats with an episode of hypocapnia or hypoxemia intraoperatively developed neurological signs and died from a CPA prior to discharge.

The incidence of postoperative UTI in the current study (20.5%) was lower than described in the recently published retrospective study by Kulendra et al (31%).[17] This could be due to the small number of cases included in our study or to the discontinuation of antimicrobial treatment immediately postoperatively in cats with negative cultures in the other study,[17] which is in contrast to the postoperative antimicrobial protocol used in the majority of cats in our study. Nevertheless, both percentages are high, and in most cases the UTI persisted, indicating the importance of this complication, which necessitates frequent follow-up visits and eventually SUB removal, and, in certain cases, even results in death. Persistent or recurrent lower UTI and pyelonephritis are most likely due to biofilm formation and stasis.[14,28–32] A recent study showed that the presence of a preoperative UTI was a risk factor for UTI after SUB placement; equally, 4/5 cats with postoperative UTI in the current study had a

UTI preoperatively.[10] Conversely, 3/7 cats with positive cultures at presentation did not have a (persistent) UTI postoperatively.

A retrospective study in cats with SUB or ureteral stents concluded that cases that received postoperative antimicrobials (enrofloxacin and/or [potentiated] ampicillin) for a median period of 5 days were less likely to have a positive urine culture during the follow-up period.[28] Based on in vitro data, marbofloxacin seems more likely to prevent biofilm formation than amoxicillin, cefalexin, doxycycline and clindamycin.[36] Likewise, in humans, fluoroquinolones are considered to be effective in preventing biofilm formation on ureteral stents.[37] Our results were different, as all cats with persistent/recurrent UTI postoperatively received postoperative marbofloxacin, while the two cats in which antimicrobials were discontinued immediately postoperatively did not develop a UTI. The reason for this finding is unclear; prospective studies are needed to determine which antimicrobial protocol is best applied during and shortly after SUB placement. Besides, 4/5 cats in present study had a UTI resistant to fluoroquinolones.

Older cats had a significantly higher risk of developing perioperative complications and were significantly more prone to dying before discharge. Older cats are more likely to have concomitant (subclinical) diseases, which can increase the risk of perioperative complications.[38] Most non-survivors presented with severe clinicopathological abnormalities (hyperkalaemia) or concomitant diseases (hypertrophic cardiomyopathy, neoplasia), complicating pre- and postoperative stabilisation, and contributing to the development of severe intra- and perioperative complications. The perioperative mortality rate (20.8%) after SUB placement was higher than previously reported (6.0–15.4%) but similar to those for traditional techniques and ureteral stenting.[1,3,7,10,13–15,17]

This study indicated that cats that presented with a high haematocrit had a significantly higher risk of developing short-term complications. The increased haematocrit was secondary to dehydration and might therefore reflect a worse clinical condition at presentation, or indicate the presence of a longstanding illness. Unexpectedly, an increased haematocrit at presentation was not found to be a risk factor for developing perioperative complications in the present study.

The overall MST was 274 days, which is lower than previously described for SUBs (820–827 days) and lower than recorded for ureteral stents (498 days);[9,10,17] however, 11 cats were still alive at the end of the study period. The lower MST could be due to the shorter follow-up in the current study. Our surgical technique differed from the one used by Berent et al,[10] as well as Kulendra et al,[17] who placed all SUBs using fluoroscopic guidance. Lack of intraoperative fluoroscopic guidance could increase the risk of intrapelvic kinking of the nephrostomy catheter with a possible higher risk of postoperative complications.

The limitations of this study are inherent to its retrospective nature. Cases were treated by various clinicians, not all data were available in all cases and follow-up visits were not standardised. Furthermore, the limited number of cases might have resulted in type II errors. Nevertheless, the less favourable prognosis observed in this study is a true finding.

Conclusions

Although complications were similar to those previously described, the complication rate after SUB placement was higher and the overall MST considerably shorter. Despite good short-term survival, the development of complications may necessitate more frequent and intensive follow-ups. It should therefore be emphasised to owners that SUBs are not a panacaea. A fair prognosis should be communicated without idealising the MST, while owners should be well informed that follow-up can be strenuous and expensive.

Supplementary material The following files are available online:

Supplementary Table 1: Comparison of selected factors between cats that underwent subcutaneous ureteral bypass surgery and survived (n = 19) and those that did not survive (n = 5) after surgery.

Supplementary Table 2: Comparison of selected factors between cats that developed complications (n = 20) and those that did not develop complications (n = 4) after subcutaneous ureteral bypass placement.

Supplementary Table 3: Comparison of selected factors between cats that developed intraoperative complications (n = 20) and those that did not develop intraoperative complications (n = 4) after subcutaneous ureteral bypass placement.

Supplementary Table 4: Comparison of selected factors between cats that developed perioperative complications (n = 10) and those that did not develop perioperative complications (n = 13) after subcutaneous ureteral bypass placement.

Supplementary Table 5: Comparison of selected factors between cats that developed short-term complications (n = 9) and those that did not develop short-term complications (n = 9) after subcutaneous ureteral bypass placement.

Supplementary Table 6: Comparison of selected factors between cats that developed long-term complications (n = 14) and those that did not develop long-term complications (n = 2) after subcutaneous ureteral bypass placement.

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Ethical approval This work involved the use of non-experimental animals only (including owned or unowned animals and data from prospective or retrospective studies).

Established internationally recognised high standards ('best practice') of individual veterinary clinical patient care were followed. Ethical approval from a committee was therefore not specifically required for publication in *JFMS*.

Informed consent Informed consent (either verbal or written) was obtained from the owner or legal custodian of all animal(s) described in this work (either experimental or non-experimental animals) for the procedure(s) undertaken (either prospective or retrospective studies). No animals or humans are identifiable within this publication, and therefore additional informed consent for publication was not required.

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