

Tailored ureteroneocystostomy with tension-relieving techniques for benign ureteral obstruction in cats: a retrospective study of 189 cases (220 ureters)

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Objective

To describe the surgical techniques for ureteroneocystostomy in cats with benign ureteral obstruction, evaluate and compare the clinical outcomes of various techniques, and conduct meta-analyses using previously reported modalities.

Methods

Medical records of cats that underwent ureteroneocystostomy for benign ureteral obstruction between 2018 and 2024 were reviewed. Retrieved data (4 ureteroneocystostomy techniques, complications, and survivals) were analyzed. Random-effect meta-analyses with a logit transformation were conducted using previous studies on implant placement (subcutaneous ureteral bypass or ureteral stents) and traditional surgery (ureterotomy or ureteroneocystostomy).

Results

Overall, 220 ureters in 189 cats were treated with ureteroneocystostomy. Overall outcomes for all techniques were a perioperative mortality rate of 0.5% (95% CI, 0.0% to 1.6%), uroabdomen rate of 1.1% (95% CI, 0.3% to 4.0%), reobstruction rate of 8.5% (95% CI, 4.5% to 12.4%), and urinary tract infection rate of 13.2% (95% CI, 8.3% to 18.1%). These rates were lower than or similar to those in previous implant and traditional surgery studies. The 12-month survival rate was 89.4% (95% CI, 85.0% to 93.8%). Cats classified as International Renal Interest Society chronic kidney disease stage $\geq$ III at 1 month postoperatively had significantly shorter survival times than lower stages. Extravesicular, 2-layer, side-to-side ureteroneocystostomy with tension-relieving techniques reduced reobstruction risk compared with the other types of ureteroneocystostomy.

Conclusions

Tailored ureteroneocystostomy and tension-relieving techniques can result in favorable long-term outcomes and low complication rates, similar to or better than those in previous implant and traditional surgery studies.

Clinical Relevance

Ureteroneocystostomy is a primary surgical treatment for feline benign ureteral obstruction, particularly when combined with tension-relieving techniques and temporary ureteral catheterization.

Keywords: ureteroneocystostomy, ureteral obstruction, tension-relieving techniques, cats, ureterolithiasis

Feline ureteral obstruction is a well-recognized condition¹ that requires prompt diagnosis and intervention to prevent irreversible kidney damage.^{2,3} While surgery is often necessary, the choice of procedure remains debatable.⁴⁻⁹ Traditional surgical procedures, including ureterotomy and ureteroneocystostomy (UNC), have historically been associated with high morbidity, characterized by major postoperative complications (uroabdomen,

persistent ureteral obstruction, and recurrent ureterolithiasis) and increased mortality rate.^{4,10} For very proximal ureteral obstructions, UNC has been described as less favorable^{4,11,12} compared to other surgical methods, such as ureterotomy and implant placement (ureteral stent or subcutaneous ureteral bypass [SUB]).^{13,14}

Recently, SUB device placement has emerged as an alternative to traditional surgery.¹ Subcutaneous ureteral bypass device placement offers certain advantages; however, it is associated with complications, such as device occlusion,^{6,14-17} urinary tract infections,^{14,15,17-22} and dysuria.^{6,14,16,18,21} Furthermore, SUB devices require long-term maintenance, including routine flushing,¹⁴ which can incur ongoing costs and may not be suitable

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for all owners. These factors highlight the need for reassessment of traditional surgeries.

We previously described extravesicular, 2-layer, side-to-side UNC combined with tension-relieving techniques (ETSUTT), specifically for treating feline unilateral proximal ureteral obstruction near the ureteropelvic junction, and reported favorable clinical outcomes.⁹ The possible advantage of UNC, regardless of technique, is the reduced risk of subsequent obstruction due to the wider lumen and shorter length of the ureter, which allows spontaneous passage of small nephroliths into the bladder.^{9,23} Recent studies have reported favorable outcomes with UNC^{8,23}; thus, we incorporated various combinations of tension-relieving techniques and refined our anastomotic techniques, including strategic use of stay sutures, loose suturing of the bladder seromuscular layer to the ureteral adventitia, and the 2-layer side-to-side anastomosis technique into the traditional UNC to reduce complications such as uroabdomen and ureteral anastomotic stricture.

We hypothesized that various forms of UNC would be a safe and effective treatment option for feline ureteral obstruction when conducted with appropriately tailored tension-relieving and anastomotic techniques based on the ureteral condition, such as the cause and location of obstruction and whether it is unilateral or bilateral, providing favorable long-term outcomes. The objectives of this study were to describe the 4 different types of UNC techniques and tension-relieving techniques used in cats with ureteral obstruction to conduct a retrospective study comparing the clinical outcomes among these surgical techniques, and to conduct meta-analyses of previous reports on implant placement and traditional surgery.

Methods

Case selection

Medical records of cats diagnosed with benign ureteral obstructions that underwent various forms of UNC at Matsubara Animal Hospital between July 2018 and December 2024 were retrospectively reviewed. Cats with complete records and a ≥ 6 -month follow-up period were included. Ten ETSUTT cases were previously reported.⁹ All owners provided written informed consent regarding the anesthetic, surgical options, and possibility of intraoperative procedural modification.

The collected data included signalment; preoperative and postoperative blood test results; preoperative urinalysis results; preoperative, intraoperative, and postoperative urine culture results; diagnostic imaging findings (preoperative and postoperative abdominal ultrasonography [AUS], preoperative CT, and intraoperative fluoroscopy); cause of obstruction; surgical procedure details; and clinical outcomes. When a cat died, the cause of death was recorded. The intraoperative period was defined as the time from anesthesia induction to the end of surgery, while the perioperative period extended from the end of surgery to hospital discharge. The follow-up periods were categorized as short-term (from hospital discharge to 30 days postoperatively) or long-term (> 30 days postoperatively). Early dislodgement was defined as unintentional ureteral catheter removal occurring within 5 days after placement.

Diagnosis and preoperative management

Ureteral obstruction was diagnosed by AUS in all cats. Urinalysis was performed at presentation or preoperatively, depending on clinical status, and urine culture was obtained when infection was suspected. Preoperative medical management included IV or SC fluids (lactated Ringer solution), tamsulosin (25 to 50 $\mu\text{g}/\text{cat}$, PO, q 24 h), prednisolone (0.5 to 1 mg/kg, SC or PO, q 24 h), and buprenorphine (0.01 to 0.02 mg/kg, IV, SC, or sublingual, q 8 to 12 h). Antibiotics were administered on the basis of culture results, and maropitant (1 mg/kg, IV or SC) was given as needed. Clinically stable cats that maintained an appetite were medically managed for approximately 1 to 2 weeks before surgery. In anorexic or clinically deteriorating cats, surgery was generally performed within a few days. Emergency UNC was performed in cats with life-threatening hyperkalemia, fluid overload, oliguria, or anuria. Hyperkalemia was managed with calcium gluconate (85 mg/kg, IV, over 10 minutes) and/or glucose-insulin therapy (regular insulin, 1 U/cat, with dextrose, 0.5 to 1 g/kg, IV).

Surgical planning, anesthesia, and analgesia

Complete blood count, blood chemistry panel, and AUS were routinely conducted on the day of surgery for presurgical assessments. Drug selection, including perioperative antibiotics and induction agents, was based on clinician discretion. Cefazolin (22 mg/kg, IV) or cefmetazole (20 mg/kg, IV) was administered 30 minutes before inducing anesthesia and every 90 minutes intraoperatively. Cats received fentanyl (3 to 5 $\mu\text{g}/\text{kg}$, IV) and midazolam (0.1 to 0.2 mg/kg, IV) as premedication. Anesthesia was induced with propofol (5 to 6 mg/kg, IV, to effect) or alfaxalone (1 to 2 mg/kg, IV, to effect) and maintained with isoflurane in oxygen. Anesthetized cats were placed in dorsal recumbency, and nonenhanced CT was conducted with a 4- or 80-row multidetector CT scanner (Canon Medical Systems Corp) to confirm the presence, location, and number of ureteroliths and assist with surgical planning. Intraoperative analgesia was provided through a constant rate infusion (CRI) of fentanyl (10 to 20 $\mu\text{g}/\text{kg}/\text{h}$, IV).

Surgical techniques and their indications

The first author (KO) conducted all procedures using 3.5X surgical loupes. A ventral midline laparotomy was performed, and the surgical procedure was selected on the basis of CT findings (stones, obstruction site, and whether unilateral or bilateral) and intraoperative assessment (strictures and distance between the obstruction site and the bladder). In this study, tailored UNC refers to the individualized selection and combination of surgical techniques, including different types of UNC and tension-relieving procedures (e.g., psoas cystopexy, renal descensus, ureterocystopexy, and nephrocystopexy), according to the location of the obstruction, the remaining ureteral length, and the anatomical relationship between the kidney and bladder. The obstructed ureters were dissected and isolated with an umbilical tape. For mid-to-distal obstruction, the ureter was ligated proximal to the obstruction site before UNC. Otherwise, a ureteral incision was initially performed to remove the calculi and assess the feasibility of UNC.

The removed calculi were analyzed. Proximal patency was confirmed by retrograde insertion of a 3F or 4F soft polyvinyl chloride catheter (Atom multipurpose tube; Atom Medical Corp) into the renal pelvis through the incision, and urine samples were collected for culture. Distal patency was confirmed by inserting a 0.018-inch guidewire (Radifocus Guide Wire M; Terumo Corp) or 24-gauge IV catheter flushed with saline. In some patients that underwent ureterotomy, including those with bilateral obstruction, the incision was closed with a simple interrupted pattern (PDS II 7-0 polydioxanone suture; Ethicon Inc). If distal patency was not confirmed, a UNC was conducted.

Tension-relieving techniques

When excessive tension was anticipated, tension-relieving techniques were selected¹¹ on the basis of the remaining ureteral length, position of the kidney and bladder, and bladder mobility. Psoas cystopexy was considered first because of its simplicity; if this was deemed insufficient, renal descensus with or without ureterocystopexy was performed. Ureterocystopexy is detailed in our previous report.⁹ Nephrocystopexy was reserved for cases requiring additional tension reduction^{9,11} and

consisted of placing 1 or 2 simple interrupted or cruciate sutures (4-0 polydioxanone) between the caudomedial kidney and cranial bladder.

Temporary ureteral catheter placement

A temporary transurethral ureteral catheter (3F to 5F soft polyvinyl chloride catheter) with several side holes was routinely placed to provide postoperative urine drainage and prevent perioperative ureteral obstruction.⁹ In bilateral UNC cases, temporary ureteral catheters were placed when feasible. Early in the study, bilateral transurethral catheterization was avoided because of urethral diameter limitations, and the wider UNC side was left without a catheter. With increased surgical experience, bilateral ureteral catheterization became feasible: females received two 3F transurethral catheters when possible, whereas males received 1 transurethral and 1 transabdominal catheter (**Supplementary Materials S1 and S2**).

Extravesicular end-to-side UNC

Extravesicular end-to-side UNC (EESU) was considered as the first line (**Figures 1 and 2; Supplementary Material S3**). The selected tension-relieving

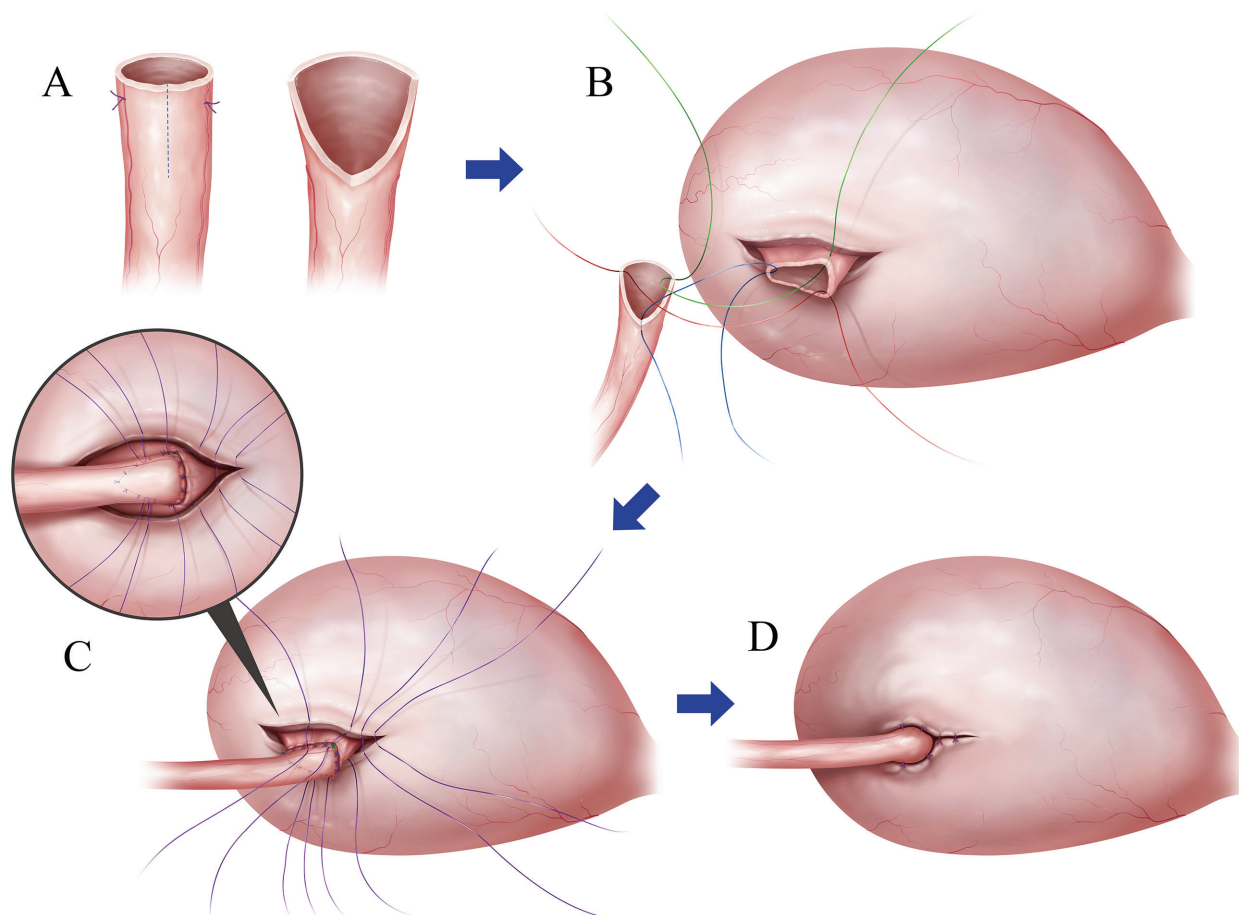


Figure 1—Surgical techniques of end-to-side extravascular ureteroneocystostomy. A—The proximal ureteral end is spatulated approximately 4 to 7 mm. B—Three stay sutures are placed to align the spatulated ureter end and incised bladder mucosa and to form shield-shaped anastomosis. The cranial end, indicated as the blue suture, is tied prior to ureteral catheter placement. C—The bladder mucosa and full layer of the ureter are sutured with a simple interrupted pattern. D—The seromuscular layer of the bladder is loosely sutured to the ureteral adventitia with a simple interrupted pattern.

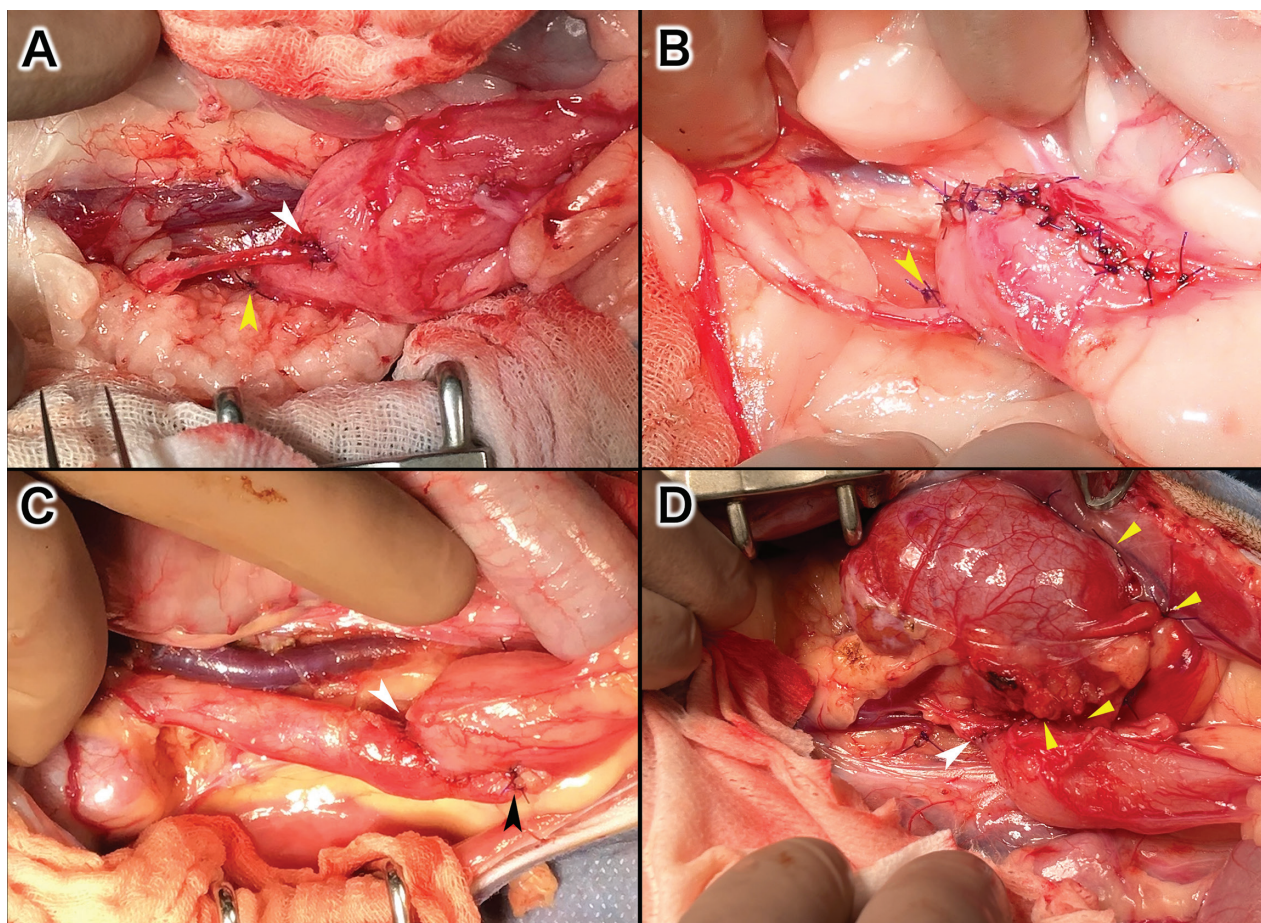


Figure 2—Intraoperative photographs illustrating 4 types of ureteroneocystostomy techniques used for feline benign ureteral obstruction. A—Extravesicular end-to-side ureteroneocystostomy (white arrowhead) with psoas cystopexy (yellow arrowhead) on the right side. B—Intravesicular end-to-side ureteroneocystostomy with psoas cystopexy (yellow arrowhead) on the right side. C—Extravesicular side-to-side ureteroneocystostomy (white arrowhead) with ureterocystopexy (black arrowhead) on the right side. D—Extravesicular 2-layer side-to-side ureteroneocystostomy (white arrowhead) with tension-relieving techniques (yellow arrowheads) on the left side.

techniques and temporary ureteral catheter placement were performed as described herein. After transection and spatulation of the ureter, a catheter was retrogradely inserted to confirm the proximal patency and collect a renal pelvic urine sample for culture. The distal segment, including the obstruction site, was dissected caudally, ligated near the bladder, and resected. Removed calculi, including those contained within the resected segment, were submitted for composition analysis.

A mucosal incision was created on the cranioventral bladder, and the spatulated ureter and bladder were apposed with 3 stay sutures to form a shield-shaped end-to-side anastomosis.^{24,25} The bladder mucosa and full layer of the ureter were sutured with a simple interrupted pattern. Finally, the seromuscular layer of the bladder was loosely sutured to the ureter, engaging the adventitia and a small portion of its underlying muscular layer, with a simple interrupted pattern.

Intravesicular end-to-side UNC

Intravesicular end-to-side UNC (IESU) was performed for cases requiring ventral cystotomy to remove

large or multiple cystoliths during the early period of this study (Figure 2; **Supplementary Material S4**). Later, such cases underwent EESU first, followed by ventral cystotomy. The selected tension-relieving techniques were performed as described herein. To perform IESU, a small dorsal bladder opening was created through a ventral cystotomy, the ureter was gently retracted into the bladder, and the spatulated ureter was anastomosed to the bladder mucosa with a simple interrupted pattern. A 3F to 4F transurethral ureteral catheter with several side holes was then placed, and the bladder was closed routinely with a full-thickness simple interrupted pattern.

Extravesicular 2-layer side-to-side UNC

Extravesicular 2-layer side-to-side UNC (ETSSU) was the same anastomotic technique as ETSUTT, indicated for ureteral obstruction at sites distal to the caudal pole of the affected kidney, with either a significantly dilated ureter or reobstruction proximal to the previous EESU site (Figure 2; **Supplementary Figure S1; Supplementary Material S5**). The selected tension-relieving techniques and temporary ureteral catheter placement were performed as described herein.

Extravesicular 2-layer side-to-side UNC combined with tension-relieving techniques

The ureteral obstruction proximal to the caudal pole of the affected kidney, including the ureteropelvic junction, ETSUTT was performed as previously described.⁹ The ETSUTT involves a modified extravesicular, 2-layer, side-to-side UNC incorporating renal descensus, ureterocystopexy, and nephrocystopexy⁹; psoas cystopexy was not used. A temporary ureteral catheter was placed as described herein (Figure 2; Supplementary Figure S1; **Supplementary Material S6**).

Leak test and closure

Fluoroscopy-guided retrograde pyelography was performed in all cases with a ureteral catheter. An iodinated contrast agent (iohexol injections, 300 mg iodine/mL) was diluted 1:1 with 0.9% sodium chloride and injected through the catheter (typically 2 to 5 mL, depending on bladder drainage). After confirming that the catheter tip was correctly positioned in the renal pelvis with no leakage observed at the UNC site, a closed suction drain (suction drainage kit; Kirikan Ltd) was placed into the abdominal cavity to monitor for urine leakage. The laparotomy was closed routinely, and a nasoesophageal feeding tube (6F to 7F soft polyvinyl chloride tube) was placed.

Postoperative management

For postoperative analgesia, fentanyl citrate (2 to 3 µg/kg/h, IV, CRI) was administered for 12 to 24 hours postoperatively, followed by buprenorphine (0.01 to 0.02 mg/kg, IV or SC, q 8 to 12 h) for 3 to 4 days, or a fentanyl patch (12.5 µg/h) applied immediately postoperatively. The CRI of fentanyl citrate was tapered as needed. Postoperative daily monitoring variables included body weight, kidney function parameters (BUN, creatinine, and electrolytes), drainage volume, urine output, and AUS. Complete blood count and total serum protein were routinely assessed the day after surgery and subsequently monitored at appropriate intervals. Intravenous fluids (lactated Ringer solution, rate adjusted to hydration status and urine output) were administered as supportive care, and IV antibiotics were continued prophylactically for 5 to 7 days, with the use of the same antibiotic given before anesthesia. Enteral feeding via a nasoesophageal tube was implemented when necessary. For cats with positive urine cultures, oral antibiotics were prescribed for 10 to 21 days after discharge. Urine output was monitored for approximately 5 days with a closed collection bag. In bilateral catheter cases, each side was recorded separately and summed. In some cats, the catheter was secured into absorbent pads and tucked under the postoperative clothes (Elizabeth Wear; Strawhouse Inc) to avoid catheter dislodgement. The ureteral catheters were typically removed 5 days postoperatively, usually without sedation by cutting the fixation suture and gently withdrawing the catheter. Alfaxalone (1.5 to 3 mg/cat, IV) was used if needed. The cats were discharged once kidney function parameters and urine output had plateaued.

Follow-up

A postoperative follow-up included physical examination, blood work (CBC, total serum protein, BUN, creatinine, calcium, phosphorus, sodium, potassium, and chloride), and AUS, typically at 10 to 14 days with suture removal. A subsequent follow-up examination (blood work and AUS) was conducted 30 days postoperatively for clinically stable cats. Further follow-ups were scheduled at individualized intervals (typically every 2 to 6 months) to monitor renal function and detect potential reobstruction and extended when renal parameters remained stable. Urinalysis was performed at the clinicians' discretion, and urine culture was submitted when infection was suspected on the basis of clinical signs or urinalysis. Renal pelvic size was measured with AUS in the transverse plane, and abnormalities were recorded when present. Follow-up information was obtained from medical records or, when necessary, from primary clinicians or owners via email or phone calls.

Statistical analysis

Associations between categorical variables were evaluated with the Fisher exact test. Random-effects meta-analyses were performed to estimate pooled outcome proportions, and forest plots were generated to visualize study-level and pooled effects. Risk factors for postoperative ureteral reobstruction were assessed with penalized logistic regression, and survival analyses were conducted with Cox proportional hazard models and Kaplan-Meier methods. Detailed statistical procedures, model specifications, and software information are provided in **Supplementary Material S7**.

Results

Signalment

A total of 191 cats underwent UNC, and 2 were excluded (incomplete records, $n = 1$; concurrent ureteral stent placement, 1), leaving 189 cats for analysis. Overall, 220 UNCs were performed for 203 anesthetic events in 189 cats. These included spayed females ($n = 102$), neutered males (82), intact females (4), and 1 intact male. Median age at surgery was 6.8 years (range, 1.1 to 17.8 years), and median body weight was 3.7 kg (range, 1.5 to 8.1 kg). The most common breeds were domestic shorthair ($n = 91$), Scottish fold (32), and American shorthair (15; **Supplementary Table S1**). The most frequent presenting signs included anorexia (168 of 189 [89%]), vomiting (103 of 189 [54%]), lethargy (93 of 189 [49%]), and hematuria (24 of 189 [13%]; **Supplementary Table S2**).

Diagnostic findings and preoperative management

Table 1 shows the results of the preoperative and postoperative kidney function parameters and renal pelvic diameter measured with AUS. The median PCV at initial presentation was 33% (range, 16% to 50%; reference interval, 29% to 45%), and 67 of 189 cats (35%) were anemic (PCV < 30%). Eight cats (4.2%) received blood transfusions for anemia preoperatively. Azotemia was observed in 173 of 189 cats (92%) on the basis of BUN (> 32.8 mg/dL) and creatinine (> 1.8 mg/dL) concentrations. Preoperative hyperkalemia and hyperphosphatemia were observed in 54 of

Table 1—Median values for blood work and renal pelvis diameter variables of 189 cats (220 ureters) treated with ureteroneocystostomy.

Time point	BUN (mg/dL) RI: 17.6–32.8 mg/dL	n	Creatinine (mg/dL) RI: 0.8–1.8 mg/dL	n	Potassium (mEq/L) RI: 3.4–4.6 mEq/L	n	Phosphorus (mg/dL) RI: 2.6–6.0 mg/dL	n	Renal pelvis diameter (mm) RI: < 2 mm	n
Preoperative	83.5 (20.1–278.5)	203	5.1 (1.3–27.8)	203	4.3 (2.2–9.1)	203	6.2 (1.7–34.6)	181	7.6 (1.4–38.4)	218
Discharge	31.1 (10.4–173.8)	202	1.8 (0.7–9.6)	202	4.2 (2.9–5.7)	201	4.7 (1.5–10.1)	60	2.6 (0.5–22.1)	211
1 mo	36.0 (15.0–130.7)	188	1.8 (0.7–7.1)	197	3.9 (3.0–5.7)	186	4.0 (1.7–10.4)	107	1.4 (0.5–12.0)	201
3 mo	38.3 (18.1–176.2)	163	1.9 (0.6–7.2)	167	3.9 (2.1–5.3)	149	4.2 (2.4–12.5)	102	1.0 (0.4–8.1)	158
6 mo	37.2 (20.5–146.0)	134	1.9 (0.8–7.1)	138	4.0 (3.2–5.4)	115	4.2 (1.6–14.1)	89	1.0 (0.5–9.3)	116
9 mo	35.0 (17.1–129.8)	114	1.9 (0.9–6.5)	115	4.0 (2.8–5.4)	100	3.9 (2.9–12.4)	70	1.0 (0.5–9.0)	96
12 mo	33.5 (16.0–164.4)	122	1.9 (0.9–9.3)	123	3.9 (2.9–5.1)	104	4.0 (2.6–15.0)	78	1.0 (0.5–9.8)	95
Last follow-up*	38.0 (17.0–283.2)	187	2.0 (1.0–15.2)	189	4.0 (3.0–5.4)	151	4.1 (1.7–31.4)	123	1.0 (0.4–9.8)	220

Values are presented as median and range.

RI = Reference interval.

*Median follow-up time was 868 days (range, 3 to 2,459 days).

189 cats (29%) and 91 of 169 cats (54%), respectively. Among the cats with hyperkalemia, 10 presented with life-threatening elevations requiring emergency stabilization, including calcium gluconate ($n = 1$), glucose-insulin therapy (6), or both (3). Of the 189 cats, 29 (15%) had bacteriuria confirmed by bacterial culture ($n = 24$) or microscopic examination (5) of preoperative or intraoperative urine samples. The most common isolates were *Escherichia coli* ($n = 9$) and suspected extended-spectrum β -lactamase-producing *E coli* (3); **Supplementary Table S3** shows details of all identified organisms.

Collectively, 257 ureteral obstructions were identified by preoperative AUS in 189 cats. Bilateral ureteral obstruction was diagnosed in 54 cats (28.6%). The median preoperative renal pelvic diameter in the affected kidney was 7.4 mm (range, 1.4 to 38.4 mm; reference interval, < 2 mm).²⁶ In 2 cats, the renal pelvic diameter was not measured because a nephrostomy tube was placed at the referring clinic and no visible dilation was observed.

On the basis of AUS and/or CT, nephroliths were identified in 184 of 240 kidneys (77%) that underwent ureteral surgery (UNC or ureterotomy). The location of ureteral obstruction was recorded in 239 of 240 surgically managed ureters and classified as proximal (98 of 239 [41%]), mid (79 of 239 [33%]), or distal (62 of 239 [26%]) on the basis of AUS, CT, and intraoperative findings. When multiple ureteroliths were present, the most proximal stone was used to define the obstruction site. Among the 240 ureters, the most common cause of obstruction was ureterolithiasis alone (173 of 240 [72.1%]), followed by ureterolithiasis with stricture (33 of 240 [3.8%]) and stricture alone (7 of 240 [2.9%]). The other causes are shown in **Supplementary Table S4**.

Surgical interventions and types of UNC

Supplementary Figure S2 depicts the distribution of intervention and corresponding ureteral counts. The median anesthesia and surgical times were 180 minutes (range, 107 to 346 minutes) and 134 minutes (range, 78 to 288 minutes), respectively. In total, 220 of 257 obstructed ureters (85.6%) underwent UNC: 153 EESU (69.5%), 4 IESU, 18 ETSSU, and 45 ETSUT. Among the remaining ureters in cats with bilateral obstructions, 20 (7.8%) underwent ureterotomy with contralateral UNC,

14 (5.4%) were left untreated owing to severe renal atrophy, 2 (0.8%) underwent nephroureterectomy, and 1 (0.4%) underwent nephrostomy catheter replacement for a previously placed SUB device. Fourteen cats required 2 anesthetic events: 9 for contralateral obstruction and 5 for reobstruction, with a median interval of 238 days (range, 11 to 987 days). Because several cats required multiple surgeries, perioperative variables and tension-relieving techniques were analyzed per anesthetic event rather than per cat.

Tension-relieving techniques

Tension-relieving techniques were conducted in 187 of the 203 anesthetic events (189 cats [92.1%]), most commonly psoas cystopexy alone (115 of 203). Among the remaining 16 events, tension-relieving technique was either not required (9 of 203) or a previously performed fixation was adequate (7 of 203). Details are shown in **Supplementary Table S5**.

Concurrent surgical procedures

Additional surgical procedures were conducted for 66 of the 203 anesthetic events (32.5%). The most common procedures were contralateral ureterotomy ($n = 20$), cystolith removal (15), and SUB device removal (9). The complete list is provided in **Supplementary Table S6**.

Postoperative data

Ureteral calculi were analyzed in 162 cats, with calcium oxalate predominating ($n = 158$; **Supplementary Table S7**). Median serum BUN and creatinine at discharge were 31.1 mg/dL (range, 10.4 to 173.8 mg/dL) and 1.8 mg/dL (range, 0.7 to 9.6 mg/dL), respectively. Both values were significantly lower than preoperative measurements ($P < .001$). The median PCV at discharge was 28% (range, 16% to 47%), and only 1 cat required a postoperative transfusion. The median hospitalization was 7 days (range, 4 to 20 days). Some cats recovered well despite early ureteral catheter dislodgement and were discharged within 5 days.

Complications

Intraoperative complications—Intraoperative complications occurred in 16 of 203 anesthetic events (15 of 189 cats [7.9%]), with 1 cat experiencing 2 complications during the same procedure (**Table 2**).

Table 2—Complications associated with ureteroneocystostomy in 203 anesthetic events (189 cats).

Period	No. (%) of events	No. of cats	Details
Intraoperative	16/203 (7.9)	15/189	Migration of ureteroliths into renal pelvis (8), bladder mucosal tearing during stay suture traction (2), disruption of ureterovesical anastomosis during ureteral catheter placement (2), subcapsular renal hematoma (1), difficulty in removing nephrostomy catheter from previously placed SUB device (1), obstructive swelling and iatrogenic perforation by guidewire (1)
Perioperative	45/203 (22.2)	45/189	Early dislodgement of ureteral catheter (25), perioperative reobstruction (5), nonobstructive ureterolithiasis (4), pollakiuria (3), uroabdomen due to dislodged transabdominal ureteral catheter (2), urethral obstruction (2, with 1 requiring PU), ureteral catheter breakage at the abdominal wall (1), localized infection at esophagostomy tube site (1), transient UTI (1), intravesicular blood clots (1)
Short-term	21/202 (10.4)	20/188	Pollakiuria (4, including 1 with pancreatitis), pyelonephritis (3), reobstruction (3), transient gross hematuria (2), temporary renal pelvic urolith migration into the proximal ureter (2), bacterial cystitis (2), asymptomatic bacteriuria (1), contralateral ureteral obstruction (1), urethral obstruction requiring PU (1), pancreatitis (1)
Long-term	50/187 (26.7)	50/187	Reobstruction (19 ureters, 18 cats), nonobstructive ureterolithiasis (5), single episodes of pyelonephritis (5), single episodes of bacterial cystitis (4), chronic pyelonephritis (2), single episodes of pyelonephritis and recurrent bacterial cystitis (2), urethral obstruction requiring PU (2), recurrent pyelonephritis (1), intermittent hematuria/pollakiuria (1), intermittent hematuria (1), persistent hematuria (1), recurrent bacterial cystitis (1), asymptomatic bacteriuria (7)

PU = Perineal urethrostomy. SUB = Subcutaneous ureteral bypass. UTI = Urinary tract infection.

The most common complication was the migration of ureteroliths into the renal pelvis ($n = 8$). In 4 cats, proximal ureterotomy was attempted to retrieve the migrated stone but was unsuccessful, and ETSUTT was performed by use of the same ureterotomy site. In the remaining 4 cats, stone removal was not attempted, and EESU ($n = 3$) or ETSSU (1) was performed.

Perioperative complications—Only 1 cat (0.5%) died during the perioperative period owing to respiratory arrest resulting from progressive neurological deterioration 3 days postoperatively, despite improved renal values. Meta-analysis showed that perioperative mortality in this cohort (0.5%; 95% CI, 0% to 1.6%) was lower than rates reported for implant placement (9.2%; 95% CI, 6.6% to 12.7%) and traditional surgery (16.1%; 95% CI, 11.0% to 22.9%; **Figure 3**). Other complications occurred in 45 of the 203 anesthetic events (45 of 189 cats [22.2%]), most commonly early ureteral catheter dislodgement ($n = 25$), perioperative reobstruction (5), and nonobstructive ureterolithiasis (4). Among early dislodgement cases, 5 were within 48 hours postoperatively. Uroabdomen occurred in 2 cats because of dislodgement of a transabdominal ureteral catheter (details in the *Overall* section herein).

Short-term complications—Short-term complications occurred in 21 of the 202 anesthetic events in 188 cats (20 cats [10.4%]). The most common complications included pollakiuria ($n = 4$), pyelonephritis (3), and short-term reobstruction (3; 3 ureters, summarized in the *Reobstruction* section herein).

Long-term complications—Long-term complications occurred in 50 of 187 cats (26.7%). Long-term reobstruction was the most common, affecting 18 cats (19 ureters; summarized in the *Reobstruction* section). Thirteen cats had reobstruction on the UNC side (reobstruction alone, $n = 11$; concurrent bacterial cystitis, 1;

concurrent contralateral nonobstructive ureterolithiasis, 1). Another cat developed bilateral reobstruction (UNC side and ureterotomy side). Three additional cats had reobstruction on the ureterotomy side alone, and 1 had ureterotomy-side reobstruction with pyelonephritis. Overall, long-term reobstruction after UNC occurred in 14 cats (14 ureters).

Overall

Uroabdomen associated with ureteral catheter dislodgement—Among the 5 cats that underwent transabdominal ureteral catheter placement, 2 (the first and third cases) developed uroabdomen due to catheter dislodgement rather than UNC-site leakage. One cat had ETSUTT with contralateral EESU, and the other had bilateral EESU. In both, catheter dislodgement exposed a side hole between the bladder and abdominal wall, causing urine leakage. Uroabdomen resolved promptly after catheter removal. After the third case, the technique was modified by limiting side holes to the catheter tip, placing a purse-string suture at the bladder entry, and securing the bladder to the transversus abdominis muscle. No further cases of uroabdomen occurred after the modifications. Meta-analysis showed that the incidence of uroabdomen in this study (1.1%; 95% CI, 0% to 2.5%) was lower than that reported for implant placement (12.5%; 95% CI, 7.7% to 19.4%) and traditional surgery (13.1%; 95% CI, 7.0% to 23.3%; **Figure 3**).

Reobstruction—A total of 22 ureters developed reobstruction after UNC. Reobstruction was categorized as related to perioperative edema or due to other causes (ureterolithiasis or stricture). A summary of reobstruction events by timing, cause, UNC type, and management is provided in **Supplementary Table S8**. Temporary ureteral catheter placement was successful in 213 of 220 ureters; it was not attempted in 4 earlier

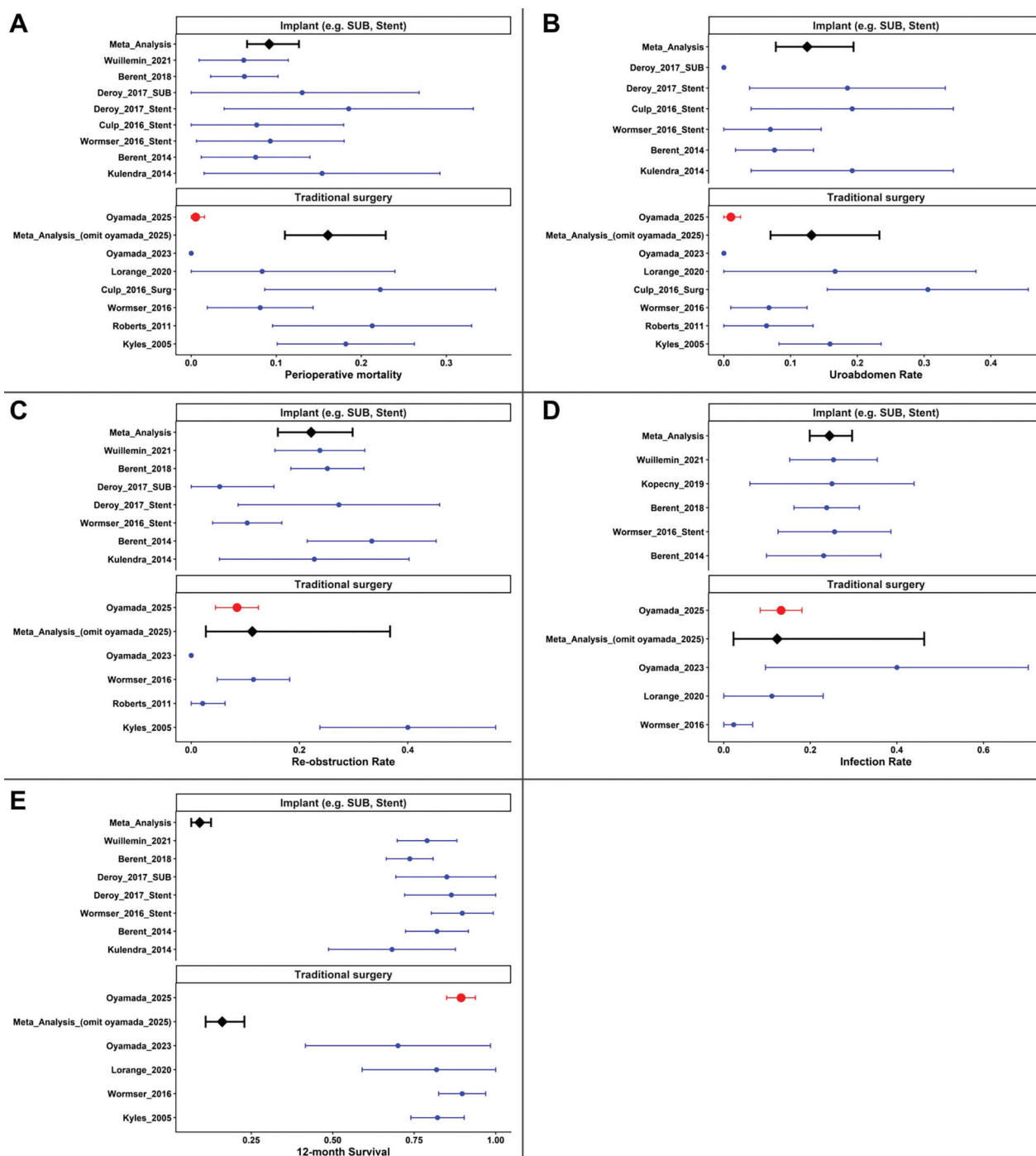


Figure 3—Forest plots comparing complication rates between implant and traditional surgery groups. Forest plots display study-level estimates (blue circles) and 95% CIs (horizontal lines) for 5 clinical outcomes: perioperative mortality rate (A), uroabdomen rate (B), reobstruction rate (C), infection rate (D), and 12-month survival rate (E). Pooled estimates from the random-effects meta-analyses are shown as black diamonds for each treatment group. Red points indicate the results of the present study (Oyamada_2025). Data were stratified by treatment methods—“implant (subcutaneous ureteral bypass [SUB], stent)” and “traditional surgery”—and studies are shown in chronological order within each subgroup. The proportions were logit transformed for analysis and back transformed for visualization.

bilateral UNC cases and was not possible in 3 ureters with a severely narrowed ureteral lumen. Among the 213 catheterized ureters, 5 catheters became dislodged within 48 hours postoperatively. Perioperative reobstruction due to edema occurred in 5 of the 12 ureters in which a catheter was either not placed

(2 of 7) or dislodged within 48 hours postoperatively (3 of 5), whereas no perioperative reobstruction occurred in any of the 205 ureters with catheterization maintained for over 48 hours. There was a significant association between perioperative reobstruction and either the absence of ureteral catheter placement or

early dislodgement within 48 hours postoperatively ($P < .001$). All perioperative reobstructions were successfully managed with surgically placed temporary ureteral stents, which were removed 1 to 1.5 months later under anesthesia transurethrally (**Supplementary Material S8**). Reobstruction from other causes occurred in 17 of 220 ureters (7.7%) that underwent UNC: 3 ureters in the short term and 14 in the long term. Causes included ureterolithiasis ($n = 16$) and stricture (1). The median time to reobstruction was 252 days (range, 15 to 682 days). Surgical management included revision UNC at a more proximal site ($n = 5$), ureterotomy (4), and SUB placement (1). Six ureters were treated medically, and 1 cat received no further intervention at the owner's request. Among 20 ureterotomies with concurrent contralateral UNC, reobstruction occurred in 5 ureters (25%) after discharge, which was significantly higher than after UNC (17 of 220 [7.7%]; $P = .025$). Multivariate logistic regression identified that ETSUTT was significantly associated with a reduced risk of reobstruction (OR, 0.092; 95% CI, 0.001 to 0.86; $P = .034$). However, the presence of nephroliths was associated with an increased risk (OR, 9.33; 95% CI, 1.18 to 1,206.51; $P = .030$). Obstruction location, preoperative serum creatinine, and urinary tract infection showed no significant associations with the risk of reobstruction, independent of the type of UNC. Because the 4 UNC procedures used in this study incorporate various combinations of tension-relieving elements, we evaluated whether any individual component was independently associated with postoperative reobstruction. Subgroup analysis evaluating individual tension-relieving techniques showed that nephrocystopexy was significantly associated with a reduced risk of reobstruction (OR, 0.023; 95% CI, 0.0002 to 0.76; $P = .037$), whereas the other tension-relieving techniques showed no significant associations. Meta-analysis demonstrated that the reobstruction rate in this study (8.5%; 95% CI, 4.5% to 12.4%) was lower than rates reported for implant placement (22.1%; 95% CI, 16.0% to 29.8%) and similar to those for traditional surgery (11.3%; 95% CI, 2.7% to 36.7%; Figure 3).

Urinary tract infection—Positive urine cultures were observed in 25 of the 189 cats (13.2%) during long-term follow-up. The most common organisms were *Enterococcus spp* and *E coli* (Supplementary Table S3). Details of postoperative bacteriuria and urinary tract infections, including UNC types, are summarized in **Supplementary Table S9**. Chronic bacteriuria, defined as > 2 positive cultures at least 2 weeks apart, was found in 6 cats. Two had prior SUB placement that was removed for pyelonephritis. Both subsequently underwent ETSUTT but later developed chronic pyelonephritis. The remaining 4 cats underwent bilateral EESU, unilateral EESU, ETSUTT with contralateral EESU, or ETSUTT with contralateral ureterotomy. Bacteriuria at surgery was significantly associated with postoperative bacteriuria ($P < .001$). Meta-analysis showed that the infection rate in this study (13.2%; 95% CI, 8.3% to 18.1%) was lower than rates for implant placement (24.4%; 95% CI, 19.9% to 29.7%) and similar to those for traditional surgery (12.3%; 95% CI, 2.2% to 46.3%; Figure 3).

Urethral obstruction caused by passed nephroliths—Postoperative passage of nephroliths through the anastomosis caused urethral obstruction requiring perineal urethrostomy in 4 male cats (ETSUTT: 1 perioperative, 1 short-term, and 1 long-term; ETSSU: 1 long-term).

Outcome

Among the 189 cats, 48 died and 141 survived during data collection. Median follow-up time was 868 days (range, 3 to 2,487 days), and only 2 cats were lost to follow-up (at 16 and 402 days). Time to death ranged from 3 to 1,910 days postoperatively. The most common cause of death was progression of CKD ($n = 23$), followed by acute kidney injury on CKD (5), including 1 ureterotomy-side reobstruction. The other causes were nonrenal ($n = 18$; **Supplementary Table S10**), and 2 deaths were of unknown cause. Kaplan-Meier analysis showed significantly shorter survival in cats with IRIS CKD stage $\geq$ III at 1 month postoperatively than those with stage I to II ($P < .001$; **Figure 4**).

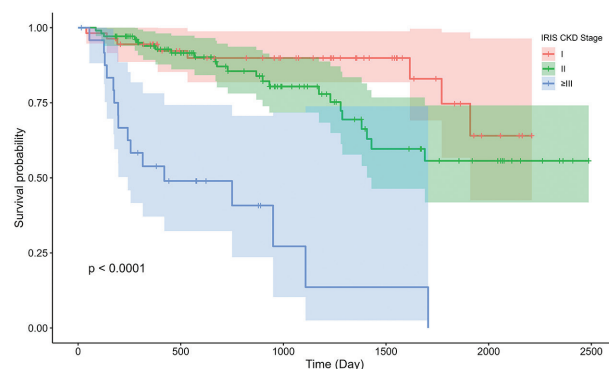


Figure 4—Kaplan-Meier survival curves stratified by International Renal Interest Society (IRIS) chronic kidney disease (CKD) stage based on serum creatinine concentration at 1 month postoperatively. Survival probability was compared by IRIS CKD staging among 3 groups: stage I (< 1.6 mg/dL), stage II (1.6 to 2.8 mg/dL), and stage III or higher (≥ 2.9 mg/dL). The shaded areas indicate 95% CIs. The log-rank test revealed a significant difference in overall survival among the groups ($P < .001$), and pairwise comparisons showed that groups in stage III or higher had significantly shorter survival times than those in stage I or II.

Overall survival curves are shown in **Supplementary Figure S3**. Cox proportional hazards model showed 1-month postoperative serum creatinine as a significant prognostic factor, with each 1.0-mg/dL increase associated with an increased risk of death (hazard ratio, 2.72; $P < .001$). Reobstruction, nephroliths, urinary tract infection, or ETSUTT technique were not significantly associated with survival. Meta-analysis showed that the 12-month survival rate in this study (89.4%; 95% CI, 85.0% to 93.8%) was higher than rates for implant placement (78.9%; 95% CI, 73.3% to 83.6%) and comparable to traditional surgery (83.7%; 95% CI, 76.4% to 89.1%; Figure 3).

Discussion

This study represents the largest cohort to date evaluating the surgical management of benign

ureteral obstructions in cats, focusing on the outcomes following UNC, particularly with modified extravesicular techniques. Ureteroneocystostomy, when conducted with appropriate surgical planning and technique selection, tension-relieving strategies, and temporary ureteral catheterization, is associated with low major complication rates and favorable long-term outcomes, highlighting its viability as a primary treatment option. Rates of perioperative mortality, uroabdomen, reobstruction, and infection were lower than or similar to those of previous reports for implant placement and traditional surgery.^{3,4,8-10,14,19,22,23} The extremely low perioperative mortality and uroabdomen rates are noteworthy. The relatively low reobstruction rate may reflect anatomical advantages of UNC.^{9,23} All types of UNC involved anastomosis between the bladder and a dilated proximal ureter, resulting in a wider lumen and shorter postoperative ureteral segment. These features, particularly in ETSUTT, may facilitate spontaneous nephrolith passage, thereby reducing reobstruction risk. In fact, 6 of the 17 ureters with postoperative reobstruction were successfully managed medically, and nonobstructive ureteroliths were observed in some cases. Our previous report also described spontaneous voiding of 3 residual nephroliths after ETSUTT,⁹ and in this study, residual nephroliths similarly migrated into the bladder, resulting in urethral obstruction in several male cats requiring perineal urethrostomy. Thus, while spontaneous stone passage is a potential benefit of UNC, clinicians should recognize the associated risk of urethral obstruction in male cats.

Multivariate analysis identified ETSUTT and nephrocystopexy as protective against reobstruction, while nephrolithiasis increased the risk. The apparent benefit of nephrocystopexy may reflect case selection, as it was mainly used in ETSUTT procedures with a wider anastomotic lumen and shorter ureteral length. Accordingly, despite statistical significance, nephrocystopexy was unlikely to provide a true clinical advantage over other tension-relieving techniques. These findings highlight the importance of adapting surgical techniques on the basis of ureteral conditions and anatomical contexts, especially for proximal anastomosis. Although ETSUTT was developed for proximal obstruction, it may offer favorable outcomes even in mid-to-distal obstruction when used as the initial approach, potentially reducing reobstruction. Further studies are needed to validate its effectiveness and refine the case-selection criteria.

The survival time in this cohort was similar to that of previous reports,^{2,6,14,17} supporting the long-term viability of surgical treatment for benign ureteral obstruction. Earlier studies identified postoperative IRIS stage and serum creatinine, especially at 3 months, as significant predictors of overall survival.^{2,14,27} In 1 study,¹⁴ each 1-mg/dL increase in serum creatinine at 3 months postoperatively was associated with a 26% increase in mortality risk, and cats in IRIS stages I to II postoperatively survived longer than those in stages III to IV. In our study, the IRIS stage at 1 month postoperatively was a significant

prognostic indicator; nevertheless, a recent study¹⁷ of SUB placement discovered no significant difference in survival between cats classified as IRIS stages II and III at 1 month postoperatively, suggesting that treatment modality, sample size, or case selection may explain discrepancies. These findings emphasize the importance of meticulous renal function monitoring and the need for studies to standardize postoperative follow-up protocols.

This study had some limitations. First, its retrospective design spanned an extended period during which surgical techniques and perioperative management may have evolved. Multivariate analysis was conducted to control for confounders; nonetheless, unmeasured factors such as variations in surgeon experience, preoperative stabilization, and decision-making processes may have influenced the outcomes. Additionally, because certain cases had a < 1-year follow-up time, complications or reobstruction after 1 year may be underestimated. Finally, statistical comparisons relied on historical data, and direct comparison with implant-based interventions was not possible within this study design. Despite these limitations, the large cohort size, consistent surgical approach, and inclusion of meta-analyses support the robustness of these findings.

While implant-based techniques, especially SUB device placement, are commonly used, UNC is an effective, implant-free treatment option for selected cases of benign ureteral obstruction, minimizing implant-associated complications and financial burden. In this study, UNC showed low major complication rates and favorable long-term outcomes, supporting its use as the primary surgical option when performed with appropriate case selection, surgical planning, tension-relieving strategies, and temporary ureteral catheterization. Further prospective studies are needed to refine surgical decision-making for UNC techniques across different anatomical contexts and to clarify the broader applicability of ETSUTT.

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Supplementary Materials

Supplementary materials are posted online at the journal website: avmajournals.avma.org.