SHORT DETOUR
The indwelling subcutaneous ureteral bypass system bypasses the ureter and diverts urine from the kidney to the bladder.

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UROLOGY/RENAL MEDICINE

Subcutaneous Ureteral Bypass as a Treatment Option for Urolithiasis in Cats

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The subcutaneous ureteral bypass (SUB) system has revolutionized the treatment of upper urinary tract urolithiasis in cats over the past 10 years. This completely indwelling system bypasses the ureter and diverts urine from the kidney to the bladder through a locking-loop nephrostomy tube and cystostomy tube, respectively. Both tubes join at a connector within the abdomen; an accessory tube from the connector to a subcutaneous shunting port allows percutaneous access to the system (**FIGURE 1**).

Knowledge of the disease process of feline upper urinary tract urolithiasis and current treatment recommendations is important for veterinary nurses. Effective client education involves understanding available treatment options, indications for intervention, and associated risks and complications. In patients that receive a SUB, long-term management of the device after placement is also required; therefore, understanding the various components is essential for a successful outcome.

FELINE URETEROLITHIASIS

Feline ureteral obstructions are increasingly being reported.[1] This increase in incidence may be attributed to greater awareness, better diagnostics, and owners electing to pursue treatment; however, these obstructions continue to be challenging to manage. More than 90% of feline ureteroliths retrieved are composed exclusively of calcium oxalate (CaOx)[2] and are not amenable to dissolution. To further complicate matters, numerous stones may be present, with a median of 2 to 4 stones per ureter[3,4] and up to 85% of cats with evidence of concurrent nephrolithiasis.[4] Partial obstructions may be monitored, but resolution of even partial obstructions can be beneficial and may maximize renal function in a cat with known ureterolithiasis due to preexisting renal disease.

OBSTRUCTIVE NEPHROPATHY

The luminal diameter of the feline ureter is 0.4 mm[1] and not likely to accommodate even small uroliths. A postrenal obstruction creates back pressure that is transmitted proximally from the site of obstruction and directly to the renal tubules. After an initial increase in both renal blood flow and glomerular pressure, both fall rapidly, resulting in a significant decrease in the glomerular filtration rate (GFR).[4] Depending on the duration of obstruction, interstitial inflammation, ischemia, tubular atrophy, fibrosis, and renal cell death may occur.[5] The longer the

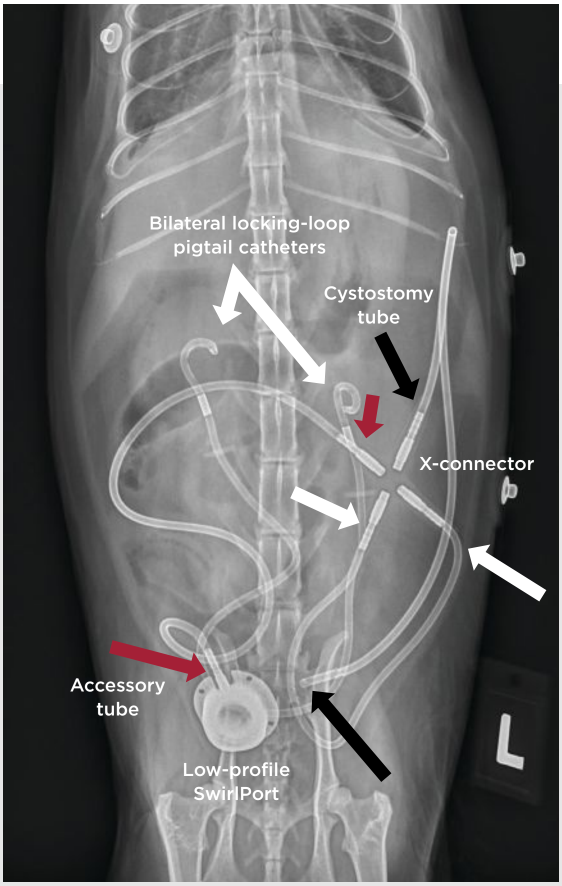

FIGURE 1. SUB 3.0 showing the X-connector with the cystostomy tube **(black arrows)** secured to the cranial portion of the connector along with the accessory tube **(red arrows)**. The bilateral nephrostomy tubes **(white arrows)** are secured at the caudal portion of the connector.

obstruction, the more significant the damage; therefore, timing is critical for restoring function to the affected kidney. Left untreated, renal injury may become irreversible with a permanent reduction in GFR and destruction of the renal parenchyma.

The presence of azotemia on bloodwork indicates that GFR has decreased to 25% of normal. When this is the result of obstruction, it indicates that the obstruction is bilateral or the unobstructed contralateral kidney is dysfunctional. Otherwise, in cases of unilateral obstruction, the contralateral kidney should be able to compensate for the decrease in GFR. Decreased renal function of the contralateral kidney may be due to a prior undetected episode of ureteral obstruction or concurrent chronic kidney disease (CKD), as up to 20% of all cats are affected by CKD during their lifetime.[6] Cats with preexisting renal compromise are at the greatest risk for an acute onset of severe azotemia with even a partial obstruction. Any delay in care may contribute to a further decrease in kidney function.

Physical Examination and Clinical Findings

Clinical signs of upper urinary tract obstruction can vary in severity at presentation, depending on factors such as duration and degree of obstruction, degree of impairment of each kidney, degree of prerenal azotemia, and presence of pyelonephritis. Cats may be asymptomatic, with ureterolithiasis diagnosed as an incidental finding or obtunded in critical condition due to uremia. Most commonly, cats present with nonspecific signs such as inappetence, vomiting, lethargy, weight loss, polyuria and polydipsia, and lower urinary tract signs (e.g., stranguria, pollakiuria, periuria, hematuria). Owing to the high incidence of ureterolithiasis, diagnostic imaging is recommended for cats with chronic nonspecific clinical signs with or without evidence of renal disease.[2]

Azotemia, metabolic acidosis, hyperphosphatemia, hyperkalemia, anemia, and leukocytosis may be present on bloodwork.[2] Urine sediment may or may not be indicative of inflammation or infection and, in cases with a complete obstruction, may only represent the nonobstructed kidney (as no urine from the obstructed kidney will be present in the bladder). If possible, a urine sample should be submitted for culture to look for a urinary tract infection (UTI) and prior to initiation of antimicrobials. A sample from the renal pelvis at time of intervention is also typically submitted for aerobic culture. Abdominal pain may be appreciated on

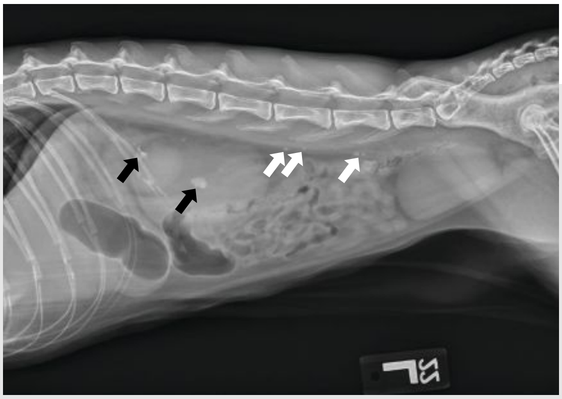

FIGURE 2. Lateral radiograph of a cat with numerous ureteroliths **(white arrows)** and bilateral nephroliths **(black arrows)**. Note the smaller right kidney cranial to the larger left kidney.

physical examination due to stimulation at the site of obstruction and/or dilation of the collection system and renal capsule.[5] Bilateral renomegaly may be present with bilateral obstruction or big kidney-little kidney palpated due to renal fibrosis of the non-obstructed kidney.

Diagnostic Imaging

The combination of radiography and ultrasonography can identify and diagnose ureteroliths, nephroliths, and signs of complete or partial obstruction.[2] Increased renal size and radiodense uroliths may be easily detected on radiographs of the upper urinary tract (**FIGURE 2**). Hydroureter seen on ultrasonography is the result of the ureteral lumen expanding with urine and is typically proximal to the occlusion (**FIGURE 3**). The ureter often becomes tortuous as ureteral peristalsis increases in an attempt to relieve the obstruction.[5] This distention and increase in intraluminal pressures can result in mild to marked renal pelvic dilation, or hydronephrosis, seen on ultrasonography as the collection system fills with urine (**FIGURE 4**). The finding of a small contralateral kidney is not uncommon with unilateral obstruction (**FIGURE 2**).

A ureteral stricture may be present in more than 25% of cats with no urolith or calcifying material documented on ultrasonography or radiographs.[4] If hydronephrosis is mild (<5 mm) and no hydroureter appreciated, advanced imaging may be indicated to identify the source and whether partial or complete obstruction is present. Computed tomography (CT) without contrast may be performed but may not provide any more clinical information than radiography

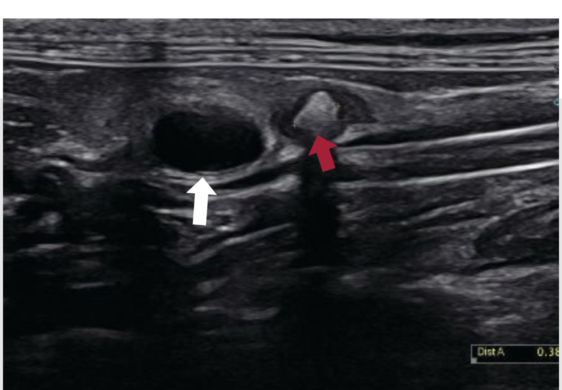

FIGURE 3. Ultrasound image of right proximal hydroureter **(white arrow)** and large (0.38 cm) ureterolith causing obstruction **(red arrow)**.

FIGURE 4. Ultrasound images showing increasing degrees of hydronephrosis due to obstruction.

or ultrasonography. CT with intravenous contrast medium is contraindicated in a renally compromised patient because contrast agents are nephrotoxic. Performing antegrade pyelography with ultrasonic guidance in a dilated renal pelvis, although uncommon, may result in uroabdomen. The obstruction may not be documented until renal access is obtained and antegrade ureteropyelography performed (**FIGURE 5**).

Treatment Options

Medical management may be attempted if the patient is stable with minimal compromise of renal function and no, or only mild, hydroureter or hydronephrosis are seen. Medical management may consist of rehydration with intravenous fluids, osmotic diuresis, medications for ureteral muscle relaxation, antimicrobials, and analgesia. Close observation of renal parameters on bloodwork and ultrasonography should be available, with a plan of intervention if the patient becomes unstable, azotemia worsens, or there is evidence of worsening or complete obstruction on serial imaging studies. Spontaneous passage of ureteroliths is often prevented by localized inflammation, edema, and spasms at the site of ureteral obstruction; ureteral strictures; or embedded ureteroliths, making this approach unsuccessful in many cats.[2,4]

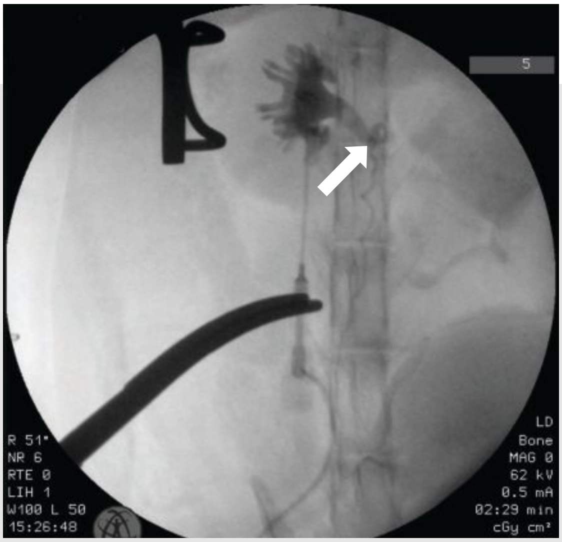

FIGURE 5. Antegrade ureteropyelogram showing partial obstruction due to proximal ureterolith. For this procedure, the renal pelvis is accessed with an 18-gauge over-the-needle catheter and placement confirmed as the needle is withdrawn and urine observed. The catheter is secured with a hemostat as a T-set is connected for pyelocentesis prior to infusion of a 50:50 contrast to 0.9% sterile saline solution. In this image, contrast enhancement of the dilated renal pelvis and a dilated tortuous ureter proximal to the ureterolith **(arrow)** are seen. Contrast is also seen going past the ureterolith down the ureter.

Traditional surgical options to relieve ureteral obstruction in cats are invasive, and perioperative and postoperative complications such as uroabdomen and persistent obstruction due to ureteral inflammation, edema, spasm, stenosis, and stricture are common.[1,4] Therefore, the best option for treatment, currently recommended by a consensus statement from the American College of Veterinary Internal Medicine, is ureteral stenting or subcutaneous ureteral bypass.[7] Ureteral stenting, in which an indwelling double-pigtail ureteral stent is inserted within the ureteral lumen, provides passive ureteral dilation and allows urine to flow through the stent or around it. In cats, placement of a ureteral stent is typically a surgical procedure but may be attempted cystoscopically in females. Although stents can be very successful, intervention-related complications are possible in cats, including the inability to place the stent due to an embedded ureterolith, a large number of ureteroliths, the narrow ureteral lumen, or the presence of a stricture.[4]

The SUB 1.0 was designed as a salvage procedure when a stent could not be placed, but it quickly gained an advantage over stents due to fewer complications and better tolerance in cats. The original design consisted of a locking-loop nephrostomy tube and a straight cystostomy tube connected to a subcutaneous, dual-armed, titanium shunting port called a SwirlPort (**FIGURE 6**).[6] The indwelling portion of the cystostomy tube has changed multiple times in an effort to increase bladder comfort. The SUB 2.0 utilizes locking-loop

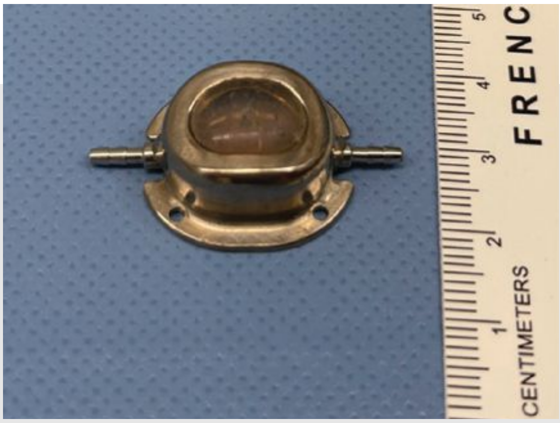

FIGURE 6. Dual-armed port of the SUB 2.0. The self-sealing silicone septum is located at the center.

pigtail cystostomy catheters and eliminates the tip of a straight catheter. The SUB 3.0 (Norfolk Vet Products, norfolkvetproducts.com) returned to a straight cystostomy tube, but with a fixed length to avoid the possibility of overinsertion within the bladder lumen. The SUB 3.0 nephrostomy and cystostomy tubes are secured to a connector that remains in the abdomen, and from there the accessory tube passes through the body wall to connect the system to the subcutaneous port. This decreases complications of kinking of catheter tubing, reduces surgical time, and allows for easier revision if required.

PLACEMENT OF SUB SYSTEM

Placement of the SUB 3.0 requires fluoroscopic and surgical assistance. Special device training and considerable experience with using guidewires and locking-loop catheters are essential.

A ventral midline laparotomy exposes the affected kidney and bladder apex (**FIGURE 7**). After obtaining over-the-needle catheter access to the renal pelvis, a modified Seldinger technique is used to place the locking-loop nephrostomy catheter over a guidewire under fluoroscopic guidance. The nephrostomy catheter is inserted over a straightener; once the straightener is removed, the catheter coils inside the renal pelvis in a pigtail configuration to prevent tip migration. A contrast study is performed to ensure there is no urine leakage before the catheter is secured. If indicated, this process is repeated in the contralateral kidney. The cystostomy catheter is placed in the bladder apex and another contrast study is performed to look for urine leakage before it is secured. All catheters are then connected to the adapter. Within the nephrostomy catheter(s) is a string that, when secured at the connector, retains the shape of the pigtail.

FIGURE 7. Ventral midline laparotomy exposing the affected kidney and urinary bladder. The perirenal fat is bluntly dissected over the caudal pole of the kidney for access to the renal pelvis.

Precision is required for the placement of all device components, including the correct configuration of catheters to either the X (bilateral system) or Y (unilateral system) connector. A team of specialists in surgery and interventional procedures, along with trained veterinary nurses, is needed to optimize patient outcomes. Full surgical guides are available online,[8] and everyone on the team who may assist with placement should be aware of the steps involved and where, when, and how complications may arise.

SUB SYSTEM MAINTENANCE

Knowledge, training, and experience with troubleshooting help ensure the system will last the patient's lifetime. With the increasing number of systems being placed, more practices with ultrasonography capabilities may be asked to take on maintenance. Familiarity with both the SUB 2.0 and 3.0 systems is required, and knowledge of which system is in place should be obtained and recorded prior to access. Detailed maintenance guides for each system are available online.[8] Regardless of the system, a non-coring Huber needle must always be used to access the shunting port. The self-sealing silicone septum at the center of the port will be compromised with a cutting needle, allowing urine to leak out at the port.

Maintenance of the SUB system involves accessing the shunting port for a urine sample, flushing the system with sterile saline to ensure patency of both the nephrostomy and cystostomy tubes, and infusing a solution of tetrasodium ethylenediaminetetraacetic acid (EDTA) as a locking solution. The tetrasodium EDTA solution is used as an antimicrobial and for prevention of mineralization. To ensure patency, sterile saline is gently agitated prior to infusion under ultrasonic guidance to identify bubbles or turbulence in the renal pelvis and bladder. Recommended intervals for flushing of the device are at discharge, 1 week postoperatively,

Subcutaneous Ureteral Bypass Flush: Step by Step

Step 1
Assess the size of the bladder and the renal pelvis of the shunted kidney(s) with ultrasonography before access. Clip the area over the port(s) free of hair and aseptically prepare the skin for access with a chlorhexidine-based solution (**FIGURE A**). Sterile technique, including sterile preparation of supplies used for access, is essential to avoid introducing infection.

Step 2
Using sterile technique, initially connect 2 empty syringes to the 3-way stopcock: one for the initial discard sample, and the second for collection of urine sample. The syringe with sterile saline will be used to ensure patency of the subcutaneous ureteral bypass (SUB) system, then tetrasodium ethylenediaminetetraacetic acid (EDTA) will be infused as a final step. Commercial SUB flush kits are available; individual components may also be used. (**FIGURE B**).

Step 3
Palpate the shunting port to locate the center of the septum, then stabilize with thumb and forefinger for advancement of the Huber needle (**FIGURE C**).

Step 4
Advance the Huber needle perpendicular to the port septum until the needle contacts the bottom of the metal reservoir (**FIGURE D**). Once placed within the silicone self-sealing septum, the needle is secure. Confirm placement by gently aspirating urine into an empty syringe. The SUB 3.0 requires the first 0.5 to 1 mL of urine to be discarded before collecting for urinalysis and aerobic urine culture. If no urine can be withdrawn, ensure placement of the needle is deep enough within the well of the port and not at an angle.

Step 5
Perform a bubble study. To create bubbles in the sterile saline, either agitate the syringe or attach an empty syringe to the 3-way stopcock and gently move the saline between the 2 syringes (**FIGURE E**). Then infuse the saline in pulses, using ultrasonography to identify turbulent flow (bubbles) in the renal pelvis. Stop immediately if overdistension of the renal pelvis is seen. Remove the same volume of saline infused. A general rule of the SUB flush is to not put in more fluid than you take out. If urine withdrawal and/or saline infusion is difficult, a fluoroscopic study may be warranted.

Step 6
Perform a bubble study for the bladder, using no more than the volume of saline infused for the renal pelvis (**FIGURE F**). Instill 2 mL of tetrasodium EDTA in small increments into the SUB system while monitoring the renal pelvis. Stabilize the port for removal of the Huber point needle. If the patient has bilateral shunting ports, repeat the process on the contralateral side.

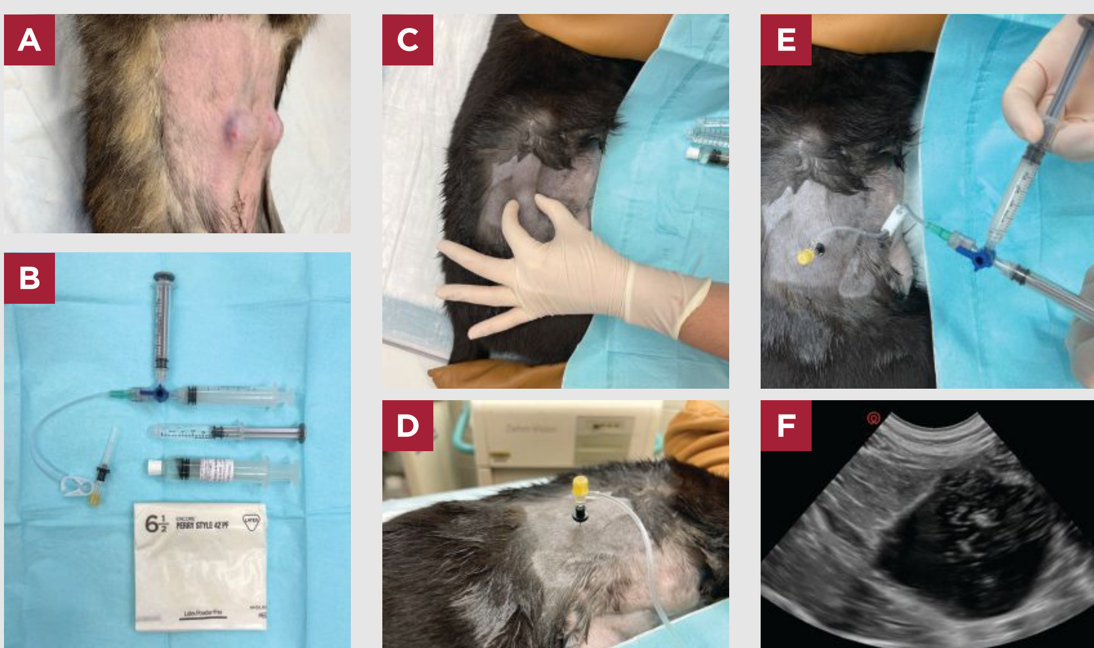

FIGURE A. Bilateral SUB 2.0 ports clipped free of hair and the skin aseptically prepared with a chlorhexidine-based solution. **FIGURE B.** Supplies used for access and flushing of the SUB port. Note the 2 syringes connected to the stopcock. The Huber point needle has a deflected or offset point that parts the silicone. **FIGURE C.** Stabilization of the shunting port for access with the Huber needle. **FIGURE D.** The Huber needle correctly placed for a SUB flush. **FIGURE E.** Agitation of sterile saline between 2 syringes for the bubble study. **FIGURE F.** Turbulent flow documented in the bladder, demonstrating patency of the cystostomy catheter.

1 month later, and every 3 months thereafter.[8] Sedation is not typically needed, but gabapentin may be helpful in some patients when given the night before and 1 to 2 hours before SUB flush.

A record should be kept of each SUB flush or access, including any measurements, the ability to withdraw and infuse, and any characteristics related to the bubble study. Any discharge and referral summaries must include instructions stating that the cat should never have a blind cystocentesis and the port should never be accessed with a cutting needle or by anyone not trained on SUB systems. The scheduled maintenance timeline should be clearly outlined for the owner.

COMPLICATIONS

Catheter-Related Complications

Cystostomy tubes can irritate the bladder considerably when in contact with the bladder trigone and ventral surface. Cats may display distress signals of dysuria, stranguria, pollakiuria, and periuria. The SUB 3.0 is designed to prevent overinsertion of the cystostomy catheter within the bladder lumen and allows cats with bilateral obstruction to have a single cystostomy tube. However, a cat with a unilateral SUB system in place can become obstructed on the contralateral side, resulting in 2 independent systems, which may also vary in design, and 2 cystostomy catheters.

Surgical Complications

Surgical complications may directly correlate with experience at the institution placing the SUB. Reported complications with the SUB 3.0 include leakage at the nephrostomy tube site; leakage at the junction of the locking-loop string of the catheter(s) to the connector; hemorrhage and clotting during nephrostomy and cystostomy tube placement; creation of a kink by pulling the locking-loop string too tight; and kinking of the catheters in the abdominal cavity or, more commonly, kinking of the tubing entering the subcutaneous space for port placement. Many of these complications have become less common with experience in placement.

System Blockage

Complete or partial blockage of the system may be apparent if renal dilation is identified at the time of presentation for a SUB flush. Other signs of a patency or functionality issue are inability to drain the bladder, resistance when removing or infusing fluid, few to no bubbles seen in the renal pelvis or bladder, or any change noted since the last SUB flush. A contrast study can determine whether blockage is present within the system; blockage may involve either a kink (dynamic or static) (**FIGURE 8**) or mineralization. If the system is not functional but no obstruction is noted, the native ureter may be patent; this can be seen with an uptake of contrast (**FIGURE 9**). In such cases, decompression and decreased luminal edema and hydrostatic pressure may have led to spontaneous resolution of the obstruction after placement of the SUB. If the ureter is patent and there are no issues with infection, an obstructed SUB may be left indwelling.

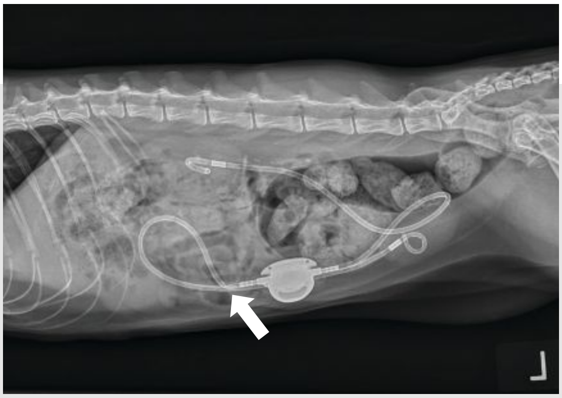

FIGURE 8. A kink **(arrow)** in the tubing of the cystostomy catheter where the catheter enters the subcutaneous space for connection to the shunting port. This required a revision and replacement of the cystostomy catheter.

FIGURE 9. A native ureter seen with uptake of contrast from the ureterovesical junction to the ureteropelvic junction **(arrow)**.

Mineralization

Calcium oxalate uroliths form in supersaturated urine with a high calcium content, which may cause issues with the indwelling device. SUB occlusion by mineralization is most likely to occur in the bladder at the indwelling portion of the cystostomy catheter but has been reported in the renal pelvis and at the shunting port.[3] Encrustation of the outside of the tubing may be seen on ultrasonography; intraluminal mineralization may not be detected. If the obstruction is complete and the kidney compromised, surgical revision is recommended. An attempt may be made to clear a partial obstruction with a mineralization protocol using the tetrasodium EDTA solution as a chelating agent. This protocol involves serial infusion of the solution into the SUB system to clear the calcium mineral deposits and has had some reported success.[9] However, use of the solution in the SUB flush protocol is mainly focused on prevention of mineralization rather than treatment. More frequent instillation of tetrasodium EDTA may be indicated in some cats.

Infection

Many factors may contribute to infection. The urinary tract is especially susceptible to infection, creating a risk for biofilm to form on implanted catheters. An established biofilm can become antimicrobial resistant.[10] Tetrasodium EDTA has antimicrobial and antibiofilm properties, and its use in the SUB flush has the goal of preventing infection. Patients with a positive urine culture or bacteriuria at the time of SUB placement are more likely to have bacteria after and to experience chronic UTIs with or without clinical signs.[3] These patients receive an antimicrobial pre-, peri-, and postoperatively and may continue therapy based on susceptibility testing for 4 to 6 weeks after placement.[8] An infection protocol using tetrasodium EDTA is available if infection cannot be cleared, but ongoing infection may ultimately require removal of the device.

PROGNOSIS

CKD may be used as a prognostic indicator for recovery of GFR.[11] Preoperative renal values, if available, may be evaluated to better assess for a positive outcome. However, there is a high likelihood of survival to discharge and good long-term survival with SUB systems. Even kidneys with evidence of severe or chronic obstruction on imaging typically recover some degree of renal function.[2] Serial monitoring of renal values, hyperphosphatemia, and anemia due to renal disease is recommended after device placement.

Ionized calcium should be monitored, as idiopathic hypercalcemia in cats may play a role in recurrence of CaOx uroliths and encrustation of the SUB system.[7] Implementation of strategies to minimize urolith recurrence is important. If a renal diet is not yet indicated based on IRIS (International Renal Interest Society) staging, a therapeutic diet for managing crystals and uroliths may be recommended. Staging of kidney disease is typically done several months after implantation to allow for renal recovery and resolution of any concurrent UTIs.

CLIENT EXPECTATIONS

Good communication with the client before implantation of a SUB system allows the veterinary team to better manage expectations. A SUB is a commitment of not only finances but also time. Prognosis, potential quality-of-life issues, risk of complications, and consent to the continuous aftercare involved in maintaining the SUB system should all be discussed. The costs of a SUB flush should be factored into device placement and the client's ability to maintain the system financially. There may be unexpected and considerable costs related to an infection or mineralization protocol, potential revision surgery, or frequent urinalysis and urine cultures due to recurrent UTIs. Persistent lower urinary tract signs can be both frustrating and disheartening to an owner after choosing surgical SUB placement. Follow-up care and treatment for concurrent CKD, if diagnosed, also requires a commitment of time, finances, and potential medication management. Frequent veterinary visits and the need to medicate their pet may affect the human-animal bond.

CONCLUSION

Early intervention is critical to preserving kidney function when an obstruction is identified. Understanding the consequences of complete and partial obstructions, available treatment options, and risks and complications of interventions enables a client to make informed decisions when timing is a factor. Collaboration is needed between primary care veterinarians and specialists for patient management to ensure longevity of the SUB system. The SUB is an exciting option for treatment of obstructive upper urinary tract disease in cats, and it continues to get better through adaptations to decrease complication rates and improve long-term patient comfort. TVN

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