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Objective—To determine outcome of renal transplantation in cats with renal failure associated with calcium oxalate urolithiasis.

Design—Retrospective case series.

Animals—19 cats.

Procedure—Medical records were reviewed for evaluation of signalment, preoperative clinical signs, physical examination results, dietary history, clinicopathologic data, abdominal imaging, postoperative diet, complications, and long-term outcome.

Results—The domestic shorthair was the most common breed represented. There were 13 spayed females and 7 castrated males. Mean age was 6.8 years. Clinical signs included weight loss, lethargy, vomiting, anorexia, polyuria, and polydipsia. Before surgery, cats received commercially available canned or dry food (n = 10), a prescription renal failure diet (5), a commercial diet to manage struvite crystalluria (1), or an unknown diet (3). Seventeen cats were anemic. All cats were azotemic. Hypercalcemia was detected in 7 cats. Abdominal imaging revealed nephrolithiasis, ureterolithiasis, or both in all cats. Median duration of survival of all cats was 605 days. Eight cats were alive 282 to 2,005 days (median, 1,305 days) after surgery. Eleven cats died 2 to 1,197 days (median, 300 days) after surgery. Five cats formed calculi in their allograft (120 to 665 days). Two of the 5 cats that formed calculi were hypercalcemic. Four of the 5 cats died following complications associated with formation of calculi.

Conclusions and Clinical Relevance—Renal transplantation appears to be a viable option for cats in renal failure secondary to calcium oxalate urolithiasis. In addition to reported complications in renal transplant recipients, formation of calculi within the allograft may also occur. (J Am Vet Med Assoc 2006;228:743–749)

During the past 2 decades, the prevalence of feline CaOx urolithiasis has been steadily increasing. According to the Minnesota Urolith Center, in 1981, 1% of uroliths analyzed from cats were composed of CaOx; in 1999, the prevalence had increased to 55%. Renal dysfunction in cats can be a complication of CaOx urolithiasis, particularly if partial or complete renal or ureteral obstruction occurs. Unfortunately, medical management that will promote dissolution of these uroliths is presently unavailable. As a result, surgery to relieve the obstruction or supportive treatment to allow time for the ureterolith to pass into the bladder are the only practical alternatives for these patients. If renal dysfunction persists after surgical or supportive treatment, treatment options may include continued medical management of the renal insufficiency or renal transplantation.

The first retrospective study on renal transplantation in cats evaluated a group of 66 renal transplant recipients from 1987 to 1996. Of 66 cats, only 1 cat had renal failure secondary to oxalate nephrosis. That cat received 2 renal allografts in a 2-week period. Oxalate nephrosis developed in both allografts, and the cat was euthanized 35 days after transplantation. Histologic examination of the native kidneys revealed tubulointerstitial nephritis with no evidence of oxalate nephrosis. The cause of oxalate nephrosis in the cat was not determined.

The prevalence of CaOx urolithiasis as the cause of renal failure and subsequent renal transplantation has been increasing. Since 1998, an active renal transplantation program has been ongoing at the University of Pennsylvania School of Veterinary Medicine and 26% (19/73) of cats that received a transplant had either confirmed or suspected CaOx urolithiasis on the basis of urolith analysis, histopathologic diagnosis, or radiographic appearance and clinicopathologic findings.

Strict guidelines regarding criteria for patient selection in the field of feline renal transplantation have contributed to the improvement in survival times over the past 17 years. According to the current veterinary literature, renal transplantation should not be performed on cats with oxalate urolithiasis because of the concern of formation of uroliths within the allograft and subsequent graft failure. Presently, no reports exist in which the outcome in this population of patients is described. The purpose of the study reported here was to determine the outcome of renal transplantation performed in 19 cats with renal failure associated with either confirmed or suspected CaOx urolithiasis. It was hypothesized that formation of uroliths can occur within the allograft of cats with preexisting oxalate urolithiasis and that formation of uroliths would be associated with shortened survival time, compared with cats that do not form uroliths.

Criteria for Selection of Cases

Medical records of cats with chronic renal failure secondary to confirmed or suspected CaOx urolithiasis

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<thead>
<tr>
<th>CaOx</th>
<th>Calcium oxalate</th>
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<td>PTH</td>
<td>Parathyroid hormone</td>
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<td>UTI</td>
<td>Urinary tract infection</td>
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and treated during an 8-year period (1997 to 2004) via renal transplantation at the University of Pennsylvania School of Veterinary Medicine (n = 13) or the University of California School of Veterinary Medicine (6) were included in the study.

Procedures
Calcium oxalate urolithiasis was confirmed in 7 cats on the basis of results of urolith analysis performed at 1 of 2 diagnostic laboratories and suspected in 12 cats on the basis of results of urinalysis, serum biochemical profile, radiographic appearance, and location of uroliths. In accordance with a recent report, CaOx uroliths were suspected when a radio-biochemical profile, radiographic appearance, and localization of uroliths. Additionally, Kaplan-Meier survival curves were generated to compare the 13 cats with CaOx urolithiasis in which a transplant was performed at the University of California with a control group of 49 cats in which a renal transplant was performed at the University of Pennsylvania with a control group of 49 cats in which a renal transplant was performed at the University of Pennsylvania and in which the underlying cause of renal failure was not CaOx urolithiasis. Additionally, Kaplan-Meier survival curves were generated to compare the 14 cats in the study that did not form uroliths within their allograft with the 5 cats that did form uroliths. For all comparisons, P ≤ 0.05 was considered significant.

Results
Signalment and physical examination—Various breeds were represented, including domestic shorthair (n = 16), domestic longhair (1), Tonkinese (1), and Siamese (1), and there were 13 spayed females and 7 castrated males. Ages of cats ranged from 2 to 12 years (mean, 6.8 years). Preoperative clinical signs included weight loss (n = 12), lethargy (11), vomiting (9), anorexia (8), decreased appetite (6), and polyuria-polydipsia (9). Duration of clinical signs was recorded for 11 cats and ranged from 17 to 913 days (median, 90 days). Physical examination revealed emaciation (n = 11), dehydration (6), systolic heart murmur (5), bilateral small kidneys (4), unilateral kidney enlargement (1), and halitosis (1).

Preoperative treatment—Prior to surgery, cats received commercially available canned or dry food (n = 10), a prescription renal failure diet (5), a commercial diet to manage struvite crystalluria (1), or an unknown diet (3). Nine cats had been given fluids SC (lactated Ringer’s solution or a balanced crystalloid solution) prior to referral, and all cats received fluids IV at the time of referral (balanced crystalloid solution). Eight cats were given an antacid (cimetidine [n = 4], ranitidine [3], or famotidine [1]), 5 cats were given phosphate binders, and 4 cats were given erythropoietin. Two cats received amlodipine for hypertension. 2 cats received cyproheptadine as an appetite stimulant, and 1 cat received pain medication (butorphanol). In addition, 1 cat had been given enrofloxacin IV for 1 week, and a second cat had been given enrofloxacin orally for 2.5 weeks prior to referral. Four cats were treated with preoperative hemodialysis, and feeding tubes were placed in 3 cats (gastrostomy tube [n = 2] and nasogastric tube [1]) prior to transplantation.

Clinicopathologic findings—Seventeen cats were anemic (PCV range, 16% to 36.7%; median for all cats, 20%; reference range, 31% to 48%). All cats had high BUN (range, 46 to 248 mg/dL; median, 90 mg/dL; reference range, 15 to 32 mg/dL) and serum creatinine concentrations (range, 3.7 to 20.8 mg/dL; median, 6.7 mg/dL; reference range, 1 to 2 mg/dL), and 13 cats had high serum phosphorus concentration (range, 5.1 to 16.5 mg/dL; median for all cats, 10.2; reference range, 3.0 to 6.6 mg/dL). Hypercalcemia was evident in 7 cats (range, 11.4 to 13 mg/dL; median for all cats, 11.1 mg/dL; reference range, 9.1 to 11.2 mg/dL). Information on total calcium concentration at the time of discharge was available for 13 cats. Hypercalcemia resolved in all cats by the time of discharge. Additionally, calcium concentrations at the time of death in 8 cats or at the most recent follow-up for 5 cats (range, 139 to 981 days) were within reference range. Parathyroid hormone concentration was measured in 4 cats, and ionized calcium was measured in 6. In 3 cats, PTH concentration was high (4.6, 8.9, and 17.4 pmol/L; reference range, 0 to 4 pmol/L), and in 1 cat, the PTH concentration (2.3 pmol/L) was within reference range. Ionized calcium concentration was within reference range in 5 cats and abnormal in 1 cat (1.5 mmol/L; reference range, 1.1 to 1.3 mmol/L). Hyperkalemia was detected in 5 cats, and hypokalemia was detected in 1 cat (range, 2.4 to 6.2 mmol/L; median, 4.3 mmol/L; reference range, 3.5 to 4.8 mmol/L). Hypermagnesemia was detected in 4 of 14 cats (range, 147 to 162 mmol/L; median, 153 mmol/L; reference range, 146 to 157 mmol/L).

Analysis of urine collected via cystocentesis revealed hematuria (n = 6), acidic urine (18; pH, 5.6.5), and occasional WBCs (8). Urine specific gravity ranged from 1.006 to 1.029 (median, 1.010). Bacteria were identified in 3 cats; however, bacteriologic culture results of urine collected via cystocentesis in all 19 cats...
were negative. A urinalysis and bacteriologic culture were performed before surgery on urine collected via pyelocentesis with ultrasound guidance in 3 cats and revealed coagulase-negative Staphylococcus sp in 1 cat, a small amount of cocci and small gram-positive rods on a gram stain of broth cultures in 1 cat (no specific bacteria were identified), and no growth in 1 cat.

**Radiographic and ultrasonographic examination**—Abdominal radiography was performed in 13 cats; small kidneys were identified bilaterally in 8 cats and unilaterally in 4 cats. Nephrolithiasis was identified in 6 cats (unilateral in 1 cat and bilateral in 5 cats), and renal pelvic mineralization without nephrolithiasis was diagnosed in 6 cats. Ureteral uroliths were diagnosed in 5 cats (unilateral in 3 cats and bilateral in 2 cats). Bilateral renal and ureteral uroliths were identified in 2 cats. Cystic uroliths were identified in 1 cat.

Abdominal ultrasonography was performed in 15 cats. Renal size was measured in 5 cats, with the size of the kidney ranging from 1.9 to 3.8 cm for the right kidney and 2.5 to 4 cm for the left kidney. Bilateral nephrolithiasis was identified in 4 cats, unilateral nephrolithiasis was identified in 3 cats, bilateral ureterolithiasis was identified in 1 cat, and unilateral ureterolithiasis was identified in 7 cats. Unilateral hydronephrosis was identified in 3 cats, bilateral hydronephrosis and hydronephrosis were identified in 3 cats, bilateral hydronephrosis and unilateral hydronephrosis were identified in 4 cats, and unilateral hydronephrosis without hydronephrosis was identified in 2 cats. Three cats had no evidence of ureteral or pelvic dilatation without hydroureter. Findings of renal parenchyma; in one of the cats, mineralization was also identified on radiographs; in the second cat, only ultrasonography was performed. One cat had cystic uroliths identified ultrasonographically. Both abdominal radiography and abdominal ultrasonography were performed in 9 cats. Findings of these modalities were similar in 3 cats and different in 6 cats.

**Surgical procedure**—Two cats had surgeries prior to renal transplantation. One cat had a cystotomy at the University of Pennsylvania to remove cystic uroliths, and a second cat had bilateral ureterotomies at the University of California to remove multiple ureteral uroliths. Urolith analysis confirmed 100% CaOx monohydrate in uroliths of 1 cat and CaOx monohydrate and calcium phosphate in uroliths of the second cat. Renal transplantation was performed in all cats, as described. In 1 cat, a single urolith lodged in the distal portion of the ureter where it joins the urinary bladder was massaged into the urinary bladder and removed at the time of renal transplantation. The urolith was composed of CaOx monohydrate. In a second cat, a nephrectomy of the left native kidney was performed at the time of transplantation because of chronic pyelonephritis. In 6 of 19 cats, biopsy of a native kidney was performed at the time of the transplant. Four of 6 had chronic interstitial nephritis, 1 cat had an end-stage kidney, and 1 cat had end-stage pyelonephritis.

**Postoperative management**—Standard postoperative management was implemented in all 19 cats. A gastrostomy tube (n = 10 cats) or a left-sided esophagostomy tube (7) was placed at the time of renal transplantation for enteral administration of nutrients after surgery. Information regarding perioperative antimicrobial administration was available for 12 cats. Nine cats received cefazolin (22 mg/kg [10 mg/lb], IV, q 8 h), 2 cats received ampicillin (22 mg/kg, IV, q 8 h), and 1 cat received enrofloxacin (5 mg/kg, IV, q 24 h) during the perioperative period and until discharge. Four cats received hydralazine (2.5 mg, SC, 1 to 4 doses) for arterial hypertension after surgery. Prior to discharge, 2 cats required a second surgery (3 days after surgery in both cats) to revise the ureteroneocystostomy because of ureteral obstruction. In both cats, the ureter was transected adjacent to the bladder and reimplanted. In 1 cat, analysis of peritoneal effusion surrounding the allograft at the time of the second surgery revealed suppurrative inflammation and rod-shaped bacteria; however, results of bacteriologic culture of the effusion were negative.

Information regarding postoperative antimicrobial administration was available for 9 cats. Antimicrobials were administered for 1 to 4 weeks after surgery or until the feeding tube was removed. Seven cats received amoxicillin combined with clavulanic acid (13.75 mg/kg [6.25 mg/lb], PO, q 12 h), which was combined with enrofloxacin (5 mg/kg, PO, q 24 h) in 1 cat and with clindamycin (5 mg/kg, PO, q 12 h) in 1 cat; 1 cat received amoxicillin (22 mg/kg, PO, q 12 h), and 1 cat received clindamycin alone (5 mg/kg, PO, q 12 h). After discharge from the hospital, cats received commercially available canned or dry food (n = 4), a prescription renal failure diet (3), a commercially available diet to manage CaOx crystalluria (9), or an unknown diet (3).

**Complications and long-term outcome**—Median survival time of all cats was 605 days. All but 1 cat survived to discharge; that cat died 2 days after surgery, likely from hemolytic uremic syndrome. Eight cats were alive 282 to 2,005 days (median, 1,305 days) after surgery, and 11 cats died 2 to 1,197 days (median, 300 days) after surgery.

In 5 cats, uroliths formed in the allograft after surgery, which was diagnosed at 120 to 665 days. The location of uroliths included the ureteroneocystostomy site only (n = 2 cats), kidney and ureter sites (1), kidney and ureteroneocystostomy sites (1), and ureter and ureteroneocystostomy sites (1). In 1 cat that had uroliths only at the ureteroneocystostomy site, CaOx crystals were identified histologically in the kidney and ureter at necropsy. Two of the 5 cats with uroliths were hypercalcemic at the time of transplantation (11.7 mg/dL and 12.8 mg/dL). Of the 5 cats in which uroliths formed in the allograft, 3 were being fed prescription diets to manage CaOx urolithiasis. Of the remaining 14 cats, 6 were being fed prescription diets to manage CaOx urolithiasis.

At the University of Pennsylvania, no significant difference (P = 0.67) was detected in survival time between the 13 cats with CaOx uroliths and the con-
trol group of 49 cats without uroliths (Figure 1). Additionally, Kaplan-Meier survival curves were generated to compare the 14 cats in the study that did not form uroliths in their allograft with the 5 cats that did form uroliths. Although the median survival time was shorter for cats that formed uroliths, the difference was not significant ($P = 0.323$; Figure 2).

Four of the 5 cats that developed CaOx uroliths in the allograft died from complications associated with the uroliths. Three of the 4 cats had ureteral obstruction of the allograft secondary to calculi attached to the 8-0 nylon suture used to perform the ureteroneocystostomy (Figure 3). One of these 3 cats also had recurrent pyelonephritis of the right native kidney at 6 days (Staphylococcus sp) and 3 months (Klebsiella sp) after transplantation, which was poorly responsive to antimicrobial treatment. At 11 months after transplantation, a second cat had a ureteral stricture of the allograft ureter. Both cats were surgically treated again to relieve the ureteral obstruction caused by the calculi. In the first cat, a nephrectomy of the right native kidney was also performed, and in the cat with the ureteral stricture, the ureter was transected proximal to the stricture and reimplanted into the urinary bladder. Azotemia recurred in both cats within 3 months after surgery. One cat died and in the second cat, the owner elected euthanasia. Urolith analysis in both cats confirmed that the uroliths were 100% CaOx monohydrate. In a third cat that developed uroliths attached to the 8-0 nylon suture, the owner declined a second surgery and elected euthanasia.

The fourth cat was successfully treated for an episode of acute rejection 1 month after transplantation. Abdominal radiographs obtained at the time of the rejection episode revealed some mineralization in the allograft ureter. Two years after transplantation, the cat was evaluated for an episode of vomiting. Serum biochemical analysis revealed azotemia, and abdominal radiographs and abdominal ultrasound revealed multiple uroliths in the renal pelvis and ureter of the allograft. The cat's condition continued to deteriorate, and the owner elected euthanasia. Necropsy confirmed multiple uroliths obstructing the renal pelvis and proximal portion of the ureter as well as hydroureterosis. Analysis confirmed that the uroliths were 100% CaOx monohydrate.

One cat that formed uroliths in the allograft was still alive 21 months after transplantation. The cat developed peritoneal effusion after transplantation, which was identified during a second surgery 3 days after transplantation for a possible ureteral obstruction. Because of the possibility of a bacterial infection, the cat was treated with enrofloxacin (5 mg/kg, PO, q 24 h) and amoxicillin combined with clavulanic acid (13.75 mg/kg, q 12 h). The cat developed a urinary tract infection 2 to 3 weeks after discontinuation of antimicrobial administration. Four months after surgery, the cat developed a ureteral obstruction. At surgery, adhesions were identified surrounding the proximal portion of the ureter and the allograft. Additionally, small uroliths were identified at the ureteroneocystostomy site associated with the 8-0 nylon suture material. The adhesions were broken.

Figure 1—Kaplan-Meier survival curves of 13 cats with CaOx urolithiasis (dashed line) that received a renal transplant and a control group of 49 cats without CaOx urolithiasis (solid line) that received a renal transplant.

Figure 2—Kaplan-Meier survival curves of 14 cats with CaOx urolithiasis (solid line) that received a renal transplant and in which a urolith did not form in the allograft and 5 cats with CaOx urolithiasis (dashed line) that received a renal transplant and in which a urolith did form in the allograft.

Figure 3—Ultrasonographic view of a portion of the abdomen of a cat that received a renal transplant. Notice uroliths attached to 8-0 nylon suture material at the ureteroneocystostomy site.
down, and the uroliths were removed and submitted for analysis. The uroliths were 100% CaOx monohydrate. Other causes of death after discharge included hemolytic uremic syndrome (n = 1), feline infectious peritonitis (1), allograft rejection (1), allograft torsion (1), perireteral fibrosis (1), and unknown (1).

**Urolith analysis**—Analysis of uroliths was performed in 7 cats. Six cats had 100% CaOx monohydrate uroliths, and 1 cat had a urolith composed of CaOx monohydrate and calcium phosphate prior to transplantation and 100% CaOx monohydrate at necropsy.

**Discussion**

Although urolith analysis was available for only 7 of the 19 cats, in the 12 remaining cats, mineral composition was predicted to be CaOx on the basis of radiographic and ultrasonographic findings and clinicopathologic results. All 12 cats had radiodense uroliths in the kidney, ureter, or both, and the urine was acidic. According to the Minnesota Urolith Center, most radiodense nephroliths and ureteroliths in cats are composed of CaOx and only 8% are composed of magnesium ammonium phosphate. The underlying cause of CaOx urolithiasis in the cats was not clear. Although not clearly defined, the increasing prevalence of CaOx urolithiasis in the feline population has been associated with treatments designed to minimize the recurrence of magnesium ammonium phosphate uroliths, including the consumption of magnesium-restricted acidifying diets. Prior to transplantation, only 1 cat was fed a magnesium-restricted acidifying diet to prevent struvite crystalluria. The effect of the other preoperative diets used for the cats in this study was unknown.

Domestic shorthair was the most commonly represented breed in our study, and mean age was 6.8 years, with a range of 2 to 12 years, which is similar to that presently reported in the literature. Although the number of cats in the present study was small, spayed females were more commonly affected than castrated males. This differs from findings in the veterinary and human literature, in which males seem to be predisposed to the condition. In 1 human study, androgens increased and estrogens decreased urinary oxalate excretion, plasma oxalate concentration, and renal CaOx deposition. In addition, androgens increase hepatic synthesis of oxalate, resulting in hyperoxaluria. In 1 veterinary study, a sex predilection was not detected. The reason for the prevalence of females in the present study was unclear.

Preoperative clinical signs, physical examination, and clinicopathological findings in the cats of this report supported a diagnosis of renal failure. Hypercalcemia was evident at the time of transplantation in 7 of 19 cats. This is similar to previous veterinary reports in which mild hypercalcemia has been reported in 35% of cats with CaOx urolithiasis. In contrast, only 11.5% of cats in chronic renal failure are reported to be mildly hypercalcemic. Hypercalcemia promotes urinary calcium excretion and may result in precipitation of CaOx crystals. The underlying cause of hypercalcemia in the cats of the present report was not known.

Urinalysis revealed acidic urine in all cats and hematuria in 6 cats. Acidic urine can influence the concentration or effects of certain inhibitors of CaOx crystallization and enhance promoter activity. Hematuria in 6 cats was likely associated with ongoing trauma to the urinary tract secondary to uroliths or the cystectomy that was performed. Bacteria were identified in urine obtained from the renal pelvis in 2 of 3 cats in which pyelonephritis was performed. In addition to the cats reported here, the authors have identified 5 cats with obstructive CaOx urolithiasis that have had negative results of bacteriologic culture of urine collected from the urinary bladder and positive results of urine collected by pyelocentesis. The reason for this finding is unclear. Potentially, chronic stagnation of urine within the renal pelvis as well as the potential for a urolith to act as a nidus for bacteria may contribute to this finding. Identification of a latent infection prior to transplantation is extremely important in a transplant patient receiving lifelong immunosuppression because the infection can become a clinical problem as well as potentiate an allograft rejection episode. Prior to transplantation, a cyclosporine challenge over a several-week period may be indicated to identify a latent infection. In 1 cat, a Staphylococcus sp infection was diagnosed by use of urine collected from the native kidney prior to transplantation. The infection responded to treatment with amoxicillin and clavulanic, which was chosen on the basis of culture and susceptibility testing. After antimicrobial administration, the infection recurred when the cat received a 2-week cyclosporine challenge prior to surgery. Antimicrobial administration was resumed, and a nephrectomy of the affected native kidney was performed at the time of transplantation. The cat has survived 20 months after surgery so far. In one of the transplant recipients in which uroliths developed in the allograft, pyelonephritis was not identified until after the transplant procedure.

Twelve cats had evidence of hydroureret or hydronephrosis on ultrasonographic examination. The decision to perform a renal transplant instead of a ureterotomy on those cats was made on the basis of each cat’s findings on physical examination, clinicopathologic tests, and abdominal ultrasonography. In 1 human study, 17 of 19 cats were anemic and 12 of 19 cats had a history of chronic weight loss. In the authors’ experience, performing a ureterotomy on cats with a history of chronic renal failure, including weight loss and anemia, generally results in poor long-term outcome. Additionally, ureterotomy performed on cats determined to have substantial loss of renal parenchyma on the basis of ultrasonographic examination also results in poor short- and long-term results.

After transplantation, dietary management was used in 9 of the 19 cats in an attempt to prevent development of CaOx uroliths in the allograft and further growth of uroliths remaining in the urinary tract. Interestingly, of the 5 cats in which uroliths reformed in the allograft, 3 were exclusively fed prescription diets to manage CaOx urolithiasis. Of the remaining 14 cats, 6 were exclusively fed prescription diets to manage CaOx urolithiasis. Although the number of cats is small and cautious interpretation of the data is indicat-
ed, this underscores the need for further investigation of the effects of dietary management on reformation of uroliths.

Urolith formation in the renal allografts of human patients is uncommon, with a reported incidence from 0.1% to 6.3%. As of 1999, only 100 cases of urolithiasis in the transplanted kidney had been reported in the human literature and included CaOx, calcium phosphate, struvite, brushite, carbonate apatite, and uric acid uroliths. These uroliths formed from 2 to 204 months after transplantation, with most cases detected in the first year. In the present study, formation of uroliths in the allograft of 5 cats developed from 4 to 22 months postoperatively. However, abdominal imaging was not routinely performed after transplantation in the remaining 14 cats, so the true rate of urolith formation in the allograft may have been higher. Periodic abdominal imaging is recommended in cats that receive a transplant and have a history of urolithiasis.

In humans, many factors predispose to urolith formation following renal transplantation. Previous studies have identified persistence of secondary hyperparathyroidism, recurrent infection, outflow obstruction, foreign bodies including exposed nonabsorbable suture material, and use of ureteral stents and nephrostomy tubes as major risk factors in the reformation of uroliths within the allograft of human patients.

In cats, multiple factors may have contributed to the formation of uroliths in the allograft. In human patients, mean arterial pressure, CaOx, calcium phosphate, and carbonate apatite within the graft have all been associated with an underlying or recurrent UTI. Two cats developed UTI after transplantation, 1 with chronic pyelonephritis in a native kidney and 1 with recurrent cystitis after transplantation. It is unclear whether these infections played a role in urolith formation, particularly because a UTI is often absent in cats with CaOx urolithiasis. One cat developed abdominal adhesions that caused obstruction of the allograft ureter after treatment for recurrent UTI. Whether infection caused the adhesion formation or ureteral obstruction predisposed the cat to recurrent UTI and subsequent urolith formation was unclear. Successful treatment of UTIs is challenging in renal transplant recipients receiving immunosuppressive drugs. One cat with urolithiasis after transplantation had no history of UTI but had a ureteral stricture at 11 months after surgery. In human patients, urinary outflow obstructions have also been associated with urolith formation in the allograft. Additionally, urinaria stasis in human transplant patients may exist at the ureteroneocystostomy site.

Four of the 5 cats with urolithiasis after transplantation had small, 100% CaOx monohydrate uroliths attached to the 8-0 nylon suture used to perform the ureteroneocystostomy. With this technique, sutures are not placed directly within the ureteral lumen, theoretically making it less likely for uroliths to form at this site and reducing the risk of ureteral obstruction.

An important factor in CaOx urolithiasis in humans and veterinary patients is supersaturation of urine with calcium and oxalate. In human patients, hypercalcemia with or without hypercalciuria can occur following renal transplantation and has been associated with urolith formation in the allograft. Many factors have been associated with hypercalciuria, including tertiary hyperparathyroidism, alterations in vitamin D metabolism, corticosteroid administration, and renal tubular acidosis. Hyperparathyroidism was an unlikely cause of urolithiasis in our patient population. Although 1 of 19 cats were hypercalcemic at the time of renal transplantation (including 2 of the 5 cats with reformed uroliths), none of the cats were hypercalcemic at the time of discharge or at any time during follow-up.

In humans, urinary saturation with oxalate is more important than with calcium and hyperoxaluria is usually associated with excessive oxalate content in food, increased absorption of dietary oxalate, or derangements of hepatic metabolism. In veterinary patients, hyperoxaluria has been associated with consumption of toxic amounts of oxalate or oxalate precursors (eg, ethylene glycol). No history of ethylene glycol exposure was evident in any of our patients. Primary hyperoxaluria types 1 and 2 are rare diseases caused by hepatic enzyme deficiencies that result in decreased oxalate metabolism. Increased oxalate production results in kidney failure from urolithiasis and nephrocalcinosis, and treatment involves a combined liver and kidney transplant. Primary hyperoxaluria as the cause of urolithiasis in our patients was unlikely. This inherited disease is rare in cats, with only a few reported cases in the veterinary literature. Affected cats develop acute renal failure from 5 to 9 months of age and became profoundly weak because of development of neurologic disease. All of the cats in the present study were middle-aged or older, and none had neurologic signs. In cats, there are 3 main sites of potential oxalate contribution, including the kidney, gastrointestinal tract, and liver. Because uroliths formed in the allografts in cats in the present study, the kidney was not likely the source of oxalate.

Interestingly, 1 cat in which uroliths formed in the allograft was initially treated for acute rejection. In human patients, symptoms of urolithiasis can mimic signs of acute rejection. Patients may have fever, infection, azotemia, and decreasing urine output. Graft tenderness, mimicking acute rejection, may also be present. Treatment of the patient for rejection may delay the diagnosis of urolithiasis, which can be problematic because such patients have a solitary functioning kidney and are immunosuppressed. Renal imaging is recommended in cats suspected of having a rejection episode, particularly in cats that have had urolithiasis.

Results of this study suggest that renal transplantation is a treatment option for cats with renal failure associated with CaOx urolithiasis. No difference in
long-term outcome was found between a group of 13 cats with urolithiasis and a control group of 49 cats with renal failure not related to urolithiasis. In human renal transplant patients, reformation of uroliths in the allograft does not appear to adversely affect graft outcome. Similarly, in cats with preoperative urolithiasis, formation of uroliths in the allograft did not significantly reduce survival time, compared with cats in which uroliths did not form. However, there were a small number of patients in each group, so the authors recommend further study of these 2 groups before a definitive conclusion can be made. Prevention of potential risk factors by modifying the technique used for the ureteroneocystostomy as well as more thorough screening for infection is recommended.

References