

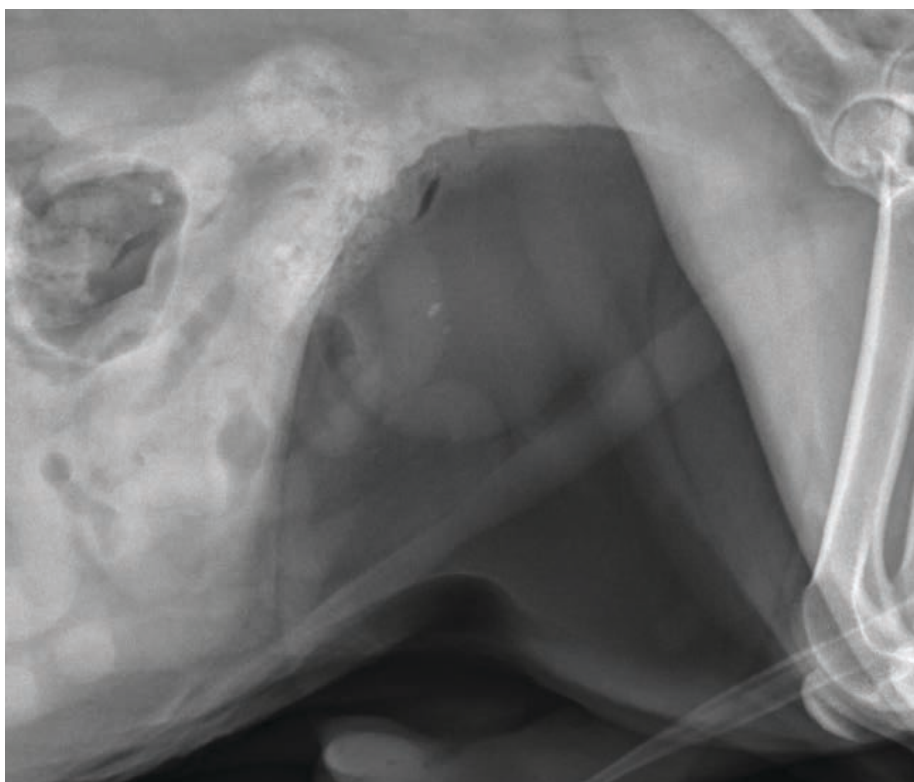
UROLOGY/RENAL MEDICINE

Understanding and Addressing Canine Calcium Oxalate Urolithiasis

Audrey K. Cook, BVM&S, FRCVS, MSc Vet Ed, DACVIM (SAIM), DECVIM (CA), DABVP (Feline)

Genna F. Atiee, DVM, DACVIM (SAIM)

Texas A&M University College of Veterinary Medicine & Biomedical Sciences, College Station, Texas



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Abstract

Calcium oxalate urolithiasis is common problem in dogs and can be the cause of substantial patient morbidity. This article provides an overview of the pathogenesis of canine calcium oxalate urolithiasis and outlines a logical approach for the evaluation and management of dogs with this condition.

Take-Home Points

- Urolithiasis should be considered in any dog with evidence of urinary tract disease.
- Calcium oxalate stones are readily identified with abdominal radiography but must be distinguished from other radiopaque uroliths.
- Decisions regarding stone removal or intervention depend on the size, location, and number of stones, along with consideration of comorbidities such as urinary tract infection and chronic kidney disease.
- Obstructive stones require immediate attention.
- Minimally invasive approaches should be prioritized over open surgical options when possible.
- Stone recurrence is common, and careful monitoring and management are needed to mitigate additional stone formation.
- When indicated, prompt referral for specialized diagnostics or treatments is expected to improve long-term outcomes for affected patients.

Calcium oxalate (CaOx) urolithiasis is an increasingly common and frequently challenging problem in canine patients. In the early 1980s, less than 10% of canine stones submitted for analysis were CaOx, but this type now accounts for one-third of stones evaluated at the Minnesota Urolith Center, with over 20 000 submissions in 2024.^{1,2} This shift may reflect the effective management of struvite stones with antibiotics and dietary modification rather than surgical removal.³ However, CaOx urolithiasis is also on the rise in humans; proposed causes include rising rates of central obesity, high dietary sodium and protein intake, and decreased dietary fiber.⁴⁻⁶ In canine patients, CaOx stones can form in both the kidneys and the bladder and are now recognized as a major cause of ureteral and urethral obstruction. As CaOx uroliths are inherently insoluble, physical removal is the only way to address stone-related morbidity. Unfortunately, many dogs experience stone recurrence despite preventive efforts; in 1 study, new stones were identified in 50% of dogs within a 2-year period.⁷

Pathogenesis and Risk Factors

CaOx urolith formation is primarily influenced by the availability of calcium and oxalate within the glomerular filtrate.⁸ However, the process is additionally influenced by a complex mix of genetic

and environmental factors. Inherited tendencies play a significant role, and breeds such as the miniature schnauzer, bichon frise, and Yorkshire terrier are consistently overrepresented.^{1,8} Sex also influences risk, with males accounting for most cases; this may to some extent reflect an increased risk for obstructive versus clinically silent urolithiasis in males compared to females.¹ However, in certain breeds, such as boxers and English bulldogs, >90% of affected dogs are male, suggesting a clear sex effect.⁹

Stone risk is also modified by the presence or absence of numerous promoters and inhibitors of crystal formation and aggregation, along with behavioral factors such as water intake and voiding behaviors (**BOX 1**).⁸ The gastrointestinal microbiome may also play a role; humans with abundant *Oxalobacter formigenes* (an enteric bacterium that ferments oxalic acid) are less likely to make CaOx stones. There is limited work on this subject in dogs, but 1 small study demonstrated that dogs with a history of CaOx urolithiasis had lower colonization rates with *Oformigenes* compared to healthy dogs, suggesting a potential protective role.¹⁷

The term “nucleation” is used to describe the transition of soluble salts (in this case, calcium and oxalate) from a liquid to a solid state. The initial stone nidus may form spontaneously (homogenous nucleation) if the

BOX 1**Factors That Influence Calcium Oxalate (CaOx) Stone Formation in Dogs****CaOx stone promoters**

- **Calcium**—Hypercalciuresis despite normal serum calcium concentration is commonly noted in CaOx stone formers, particularly miniature schnauzers.¹⁰ However, dietary calcium restriction does not appear to mitigate CaOx urolithiasis and is not recommended. Excessive renal calcium excretion is also noted in dogs with hypercalcemia, and urolithiasis is routinely identified in dogs with chronic hypercalcemic disorders such as primary hyperparathyroidism.¹¹
- **Oxalate**—Consumption of foods rich in oxalates may play a role in stone formation. High-oxalate foods (e.g., peanuts, tofu, spinach, sweet potato) should therefore be avoided.
- **Sodium**—High dietary sodium intake may promote calciuresis and should be avoided in dogs with CaOx urolithiasis.
- **Uric acid**—High urine uric acid levels interfere with endogenous stone inhibitors and appear to promote CaOx urolithiasis.¹²

- **High-protein diets**—Robust purine intake leads to uric acid generation and supports an acidic urine pH.
- **Mechanical nidus**—Suture-associated cystoliths represented > 9% of recurrent canine cystolithiasis cases in 1 study.¹³
- **Biological nidus**—Bacteria may act as a stone nidus. Positive cultures were reported in 13% of CaOx stones in 1 study, with *Escherichia coli* noted to be the common isolate.¹⁴
- **Low urine pH**—CaOx crystals are less soluble in acidic urine.
- **High urine specific gravity**—Concentrations of calcium and oxalate are higher in more concentrated urine, which promotes precipitation.
- **Incomplete voiding**—Failure to effectively empty the bladder is well recognized as a predisposing factor for urolithiasis.⁸

CaOx stone inhibitors¹²

- **Citrate**—Citrate forms soluble complexes with calcium, thereby limiting its availability to precipitate with oxalate.

- **Magnesium**—Magnesium forms soluble complexes with oxalate. It also decreases the uptake of dietary oxalate.
- **Pyrophosphate**—This is an inorganic phosphate found in blood and urine that reduces the crystallization of calcium salts.
- **Uromodulin/Tamm-Horsfall protein**—This protein is only produced in renal tubules and is the most abundant protein in urine. Deficiency in uromodulin has been linked to juvenile-onset hereditary CaOx urolithiasis type 1 in French and English bulldogs.¹⁵
- **Osteopontin/secreted phosphoprotein 1**—This is a multifunctional protein found in milk, urine, bone, and other tissues; it appears to prevent nucleation, growth, and aggregation of CaOx crystals.
- **Nephrocalcin**—This is an acidic calcium-binding glycoprotein produced by renal proximal tubular cells and is a key inhibitor of nephrolithiasis. Differences in isoforms have been reported between stone-forming and normal dogs.¹⁶

solution is oversaturated, or it can be triggered by another crystal or proteinaceous/foreign material (heterogenous nucleation). The likelihood of homogenous nucleation is indicated by the relative supersaturation (RSS) of the urine; this is calculated using measurements of specific urine components, and target ranges apply to a specified stone type in a particular species.¹⁸ However, the RSS does not address the presence or absence of inhibitors and other unmeasured substances, and a value below the upper limit does not preclude stone growth or de novo heterogeneous nucleation.

Clinical Signs

Clinical signs depend on the size, location, and number

of stones and the presence of secondary comorbidities such as urinary tract infection (UTI) or urinary tract obstruction. If stones are identified, either incidentally or in dogs with evidence of urinary tract disease, the Minnesota Urolith Center CALCulate tool can be used to predict the likelihood of CaOx.¹⁹ As a general rule, this is the most likely stone in a dog of a high-risk breed aged ≥ 3 years.

Nephrolithiasis and Ureterolithiasis

Many patients with nephrolithiasis are symptom free, and stones are often identified incidentally or during an evaluation for chronic kidney disease.

The passage of a stone down the ureter is notoriously painful in humans; affected individuals are markedly uncomfortable due to ureteral spasm and increased pressure within the renal pelvis. In contrast, clinical signs associated with ureterolithiasis are highly variable in dogs. Those with acute obstruction may be anorexic or lethargic, but discomfort is often modest and seems to subside fairly quickly, despite ongoing renal damage.

Obstructive upper urinary tract CaOx stones are routinely associated with both pyelonephritis and pyonephrosis; affected patients may be severely compromised with fever, anorexia, and abdominal pain.²⁰ Without appropriate imaging, signs may be attributed to gastrointestinal or pancreatic disease.

Cystolithiasis and Urethrolithiasis

Patients with cystolithiasis may be asymptomatic or show signs of discomfort such as pollakiuria, stranguria, and periuria. Hematuria may also be noted. Dogs with urethral obstruction may present with acute signs of distress, along with anorexia, vomiting, dehydration, and weakness. Overflow incontinence may be noted in dogs with a partial urethral obstruction. Of note, any dog that is straining to urinate and has even a modest-sized bladder is at least partially obstructed.

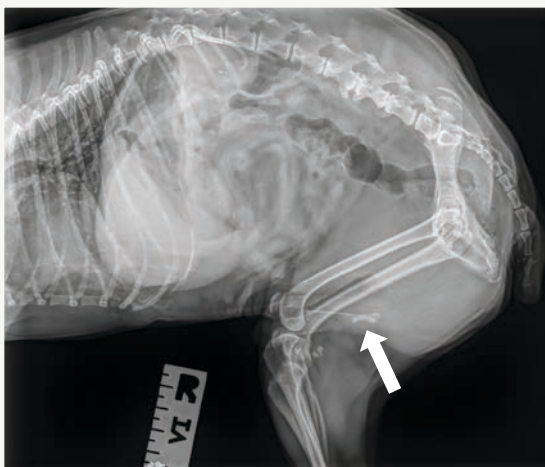


FIGURE 1. Right lateral abdominal radiograph of a 6-year-old castrated male miniature schnauzer with a large urethrolith (**arrow**). The legs have been pulled cranially (a “butt shot”) to allow for more complete evaluation of the urethra.

Diagnostics

Imaging

As CaOx stones are radiopaque, most are easily identified on abdominal radiographs, but they cannot be definitively distinguished from other radiodense stones such as struvite. It can also be difficult to differentiate renal mineralization from true nephrolithiasis, and small ureteroliths may be overlooked. Abdominal ultrasonography is therefore recommended, as this modality allows renal pelvic dilation (pyelectasia), overt hydronephrosis, and ureteral obstruction to be identified.

In dogs with evidence of lower urinary tract stones, it is important to fully assess the urethra. In males, this requires imaging in lateral recumbency with the legs pulled cranially to afford a clear view of the caudal urethra (a “butt shot”). Stones may be lodged in the urethra as it runs through the groove on the ventral aspect of the os penis and can be overlooked (**FIGURE 1**).

A “paddle” or “spoon” view, in which a radiolucent device is used to displace the small intestines and colon and compress the urinary bladder, may aid in the detection of small cystoliths (**FIGURE 2**).

Although CaOx uroliths are readily apparent on computed tomography, this imaging modality has few advantages over plain radiography and ultrasonography and is not usually indicated.

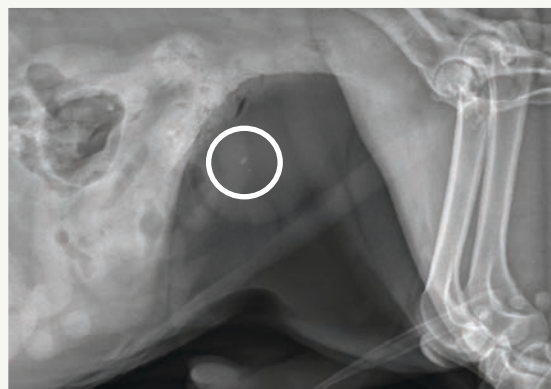


FIGURE 2. Right lateral abdominal radiograph of an 8-year-old castrated male Yorkshire terrier with 2 to 3 small cystoliths (**circle**). A radiolucent paddle has been used to compress the urinary bladder and displace overlying bowel.

Laboratory Data

Urine

A low urine pH (≤ 6) in a dog with radiopaque uroliths is supportive of CaOx; hematuria and low-grade pyuria may be noted. Secondary infection with urease-producing bacteria can alter urine pH. Crystals may be present but are not consistently observed. A quantified urine culture is indicated if the urinalysis suggests infection.

Serum Biochemistry

A routine serum biochemical profile is indicated to look for evidence of renal compromise, dyslipidemia, and hypercalcemia. Although hypercalcemia appears to be uncommon, the authors recommend measuring serum ionized calcium concentrations in every dog with calcium-containing stones, as total calcium concentrations may be within the reference range despite true (ionized) hypercalcemia.²¹ In 1 study of more than 200 dogs with primary hyperparathyroidism, almost one-third of dogs had urolithiasis.¹¹

Interventions

Not every CaOx stone needs to be removed, and decisions regarding appropriate interventions should take into consideration the number, size, and location of the stones; their current and anticipated clinical impact; presence of UTI; and nature and extent of comorbid conditions.²⁰ At least 1 representative stone should always be submitted for analysis, which should include information about the nidus, body, shell, and surface of the stone rather than just its overall composition. When possible, a stone should also be submitted for culture as results may differ from findings from urine.¹⁴

Nephrolithiasis

Any radiopaque nephrolith in a dog with acidic urine is highly likely to be CaOx. These stones are only directly addressed if they are causing renal parenchyma compression or outflow obstruction or appear to be harboring infection.²⁰ In most cases, no action is necessary, although routine ultrasonography to monitor renal status is warranted.

Options for removing nephroliths include a traditional pyelotomy or nephrotomy. Both options are complex; risks include renal pelvic or ureteral obstruction

secondary to hemorrhage, urine leakage, and nephron loss. Endonephrolithotomy can be performed with surgical access or percutaneously; in this procedure, the renal parenchyma is dilated rather than incised, and an endoscope is inserted into the renal pelvis for lithotripsy. This is significantly less invasive than traditional options but requires specific equipment and considerable expertise.²² Extracorporeal shock wave lithotripsy (ESWL) is also an option although availability is limited; this technique fragments the nephroliths using high-energy acoustic pulses.²² For both endonephrolithotomy and ESWL, double-pigtailed ureteral stents are placed to reduce the risk of obstruction; these are removed cystoscopically or under fluoroscopic guidance 2 to 3 weeks later. In exceptional cases with severe concurrent ureteral dilation, nephroliths may be retrieved from the renal pelvis via ureterotomy using a flexible scope.

Ureterolithiasis

Acute ureteral obstructions (**FIGURE 3**) may be medically managed with fluids, pain relief, and ureteral relaxants such as prazosin.²²

Dexmedetomidine is also used in humans but has not been evaluated for this purpose in dogs. However, substantial compromise to renal outflow predictably results in nephron loss, and most experts recommend intervening within 48 hours if the stone has not moved.

There are several ways to address persistent, obstructive ureteroliths. ESWL may be considered, but it is not routinely performed due to limited accessibility. However, a simpler, ultrasound-based, burst-wave

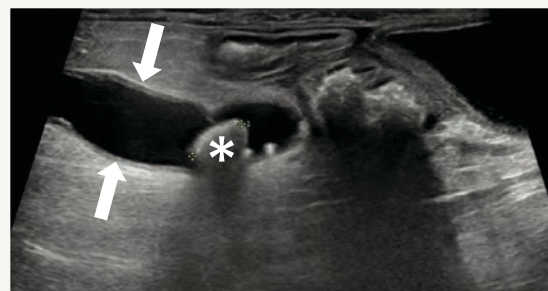


FIGURE 3. Transabdominal ultrasound image of a 6-year-old castrated male Chihuahua with recurrent calcium oxalate urolithiasis. This image shows a markedly dilated left ureter (**arrows**) with 1 large stone (**asterisk**) and some adjacent mineral debris.

lithotripter is currently under development and may be available for veterinary use within the next few years.²³ In dogs with a small number of stones, the authors' preference is for surgical ureterotomy, with temporary placement of a double-pigtailed stent under fluoroscopic guidance to reduce the risks of leakage or stricture (**FIGURE 4**). For a single distal stone, distal amputation and surgical reimplantation of the ureter may be considered. Significant surgical skill is required for both of these options.

For patients with multiple ureteroliths, the kidney may be successfully decompressed with a double-pigtailed stent. This can be placed cystoscopically with fluoroscopic assistance in most females but requires perineal urethral access or a traditional cystotomy in males. The stent allows passage of urine but is likely to become encrusted with mineral over time and may need to be periodically replaced. Surgical placement of a subcutaneous ureteral bypass (SUB) system is also an option; this requires less technical skill than ureterotomy and urine leakage is extremely unlikely (learn more about the SUB system at go.navc.com/4ovoq3q). In the authors' practice, intraoperative fluoroscopy is always used to facilitate appropriate placement of the nephrostomy tube. However, the SUB is also at risk of progressive mineralization and eventual obstruction.

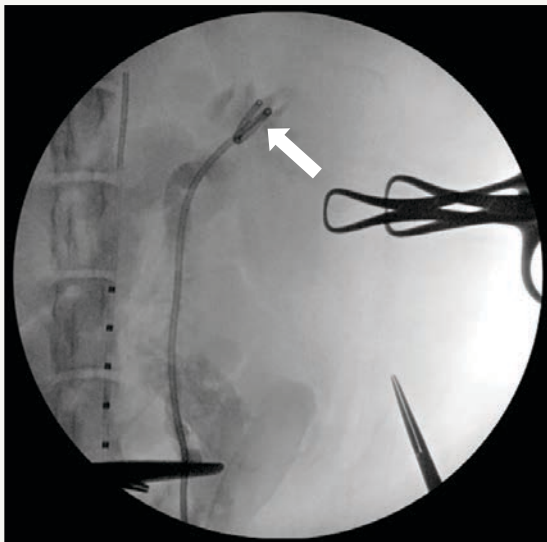


FIGURE 4. Intraoperative fluoroscopic image of the patient shown in **FIGURE 3**. The proximal (renal) end of a double-pigtailed ureteral stent (**arrow**) can be seen in this image. The stent was placed following ureterotomy for stone removal.

Minimally invasive options should be prioritized over a surgical approach, as they cause less patient morbidity and avoid issues related to stone formation secondary to a suture nidus.¹³

Cystolithiasis

Stones in the urinary bladder should be removed if they are causing clinical signs, harboring infection, or likely to cause urethral obstruction.²⁰ Minimally invasive options should be prioritized over a surgical approach, as they cause less patient morbidity and avoid issues related to stone formation secondary to a suture nidus.¹³ However, with the exception of voiding urohydropropulsion (VUH), minimally invasive approaches may require referral to a specialist facility and incur higher costs than a traditional cystotomy. Clients should be made aware of all options and supported in making treatment decisions that balance the needs and circumstances of both the patient and its caretakers.

Small stones should be addressed with VUH. VUH is a very simple procedure and is usually successful, particularly if the stones are smooth and round (learn more about VUH at go.navc.com/3JLeGCQ). Patients are briefly but deeply anesthetized, a urinary catheter is passed into the bladder, and sterile saline (approximately 7 to 10 mL/kg) is infused until the bladder is noted to be turgid. The catheter is then removed and the patient held up vertically for 45 seconds to allow stones to fall into the proximal urethra. The bladder is then expressed. Radiography or ultrasonography may be used to confirm removal of all stones. Stone size must be carefully assessed radiographically prior to VUH and correlated to expected minimal dilated urethral diameter, bearing in mind that 1 mm equals 3 Fr. Patient size may preclude VUH, which is challenging in dogs weighing more than approximately 15 kg (33 lb) or those that are morbidly obese.

Cystoscopic lithotripsy should be considered in dogs with a small number of stones that are too large for VUH. A Ho:YAG (holmium:yttrium-aluminum-garnet) or similar laser is used to fragment the stones (**FIGURE 5**). Large pieces may be retrieved using a basket; fragments can be suctioned or expelled using VUH. Most female dogs weighing > 3 kg (6.6 lb) can accommodate a neonatal cystoscope; males must be large enough to accommodate a flexible ureteroscope (usually ≈ 9 Fr, although smaller ones are available).

Patients with numerous stones measuring less than 5 or 6 mm may be managed with a percutaneous cystolithotomy (PCCL).²⁴ This option is not appropriate for dogs with a UTI as the peritoneal cavity cannot be effectively lavaged. An approximately 2-cm ventral abdominal incision is made to allow access to the bladder. In the authors' clinic, the cranioventral aspect of the bladder is sewn to the body wall and then accessed using a 6-mm ternamian trocar. Vigorous retrograde urethral lavage with a urinary catheter is used to flush stones up the trocar and out of the bladder. Residual stones are basketed out using an endoscope. Various studies suggest that PCCL may reduce surgical and hospitalization times and result in less postoperative discomfort.

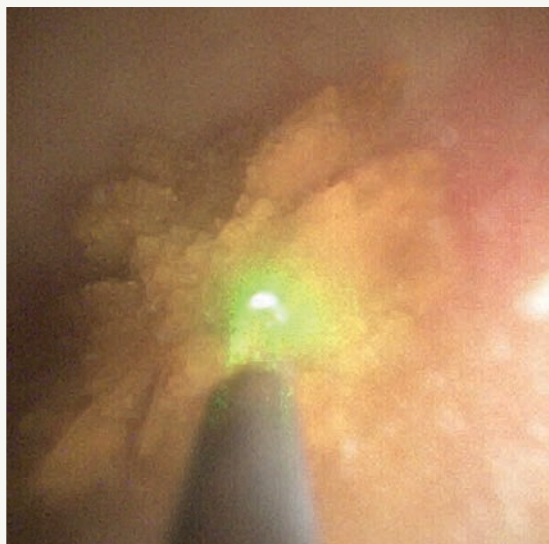


FIGURE 5. Cystoscopic image of a 7-year-old castrated male beagle with a single cystolith. A Ho:YAG (holmium:yttrium-aluminum-garnet) laser fiber is seen touching the stone. Stone dust from lithotripsy can be appreciated on the right side of the image. This stone was quickly fragmented and the remnants retrieved with an endoscopic basket.

A traditional open cystotomy is appropriate for dogs with large stones or those with a concurrent UTI. A direct endoscopic evaluation or postoperative radiography may be used to ensure all stones are removed.

Urethrolithiasis

When possible, lodged uroliths should be flushed back into the urinary bladder for removal. The authors find that the MILA International retropulsion catheter is particularly effective. Embedded stones may be fragmented with lithotripsy or retrieved endoscopically (**FIGURE 6**). Urinary diversions such as a scrotal urethrostomy should be considered if a more distal stone cannot be dislodged. Urethrotomy is generally not recommended due to the risk of stricture.

Stone Prevention

The recurrence rate for CaOx stones is high, even after successful removal, and stones left in situ are likely to grow without targeted preventive efforts.⁷ The following guidelines are appropriate for all nonhypercalcemic CaOx stone formers but are likely not appropriate for rare patients with hereditary CaOx urolithiasis type 2 (usually bulldogs, mastiffs, bassets,

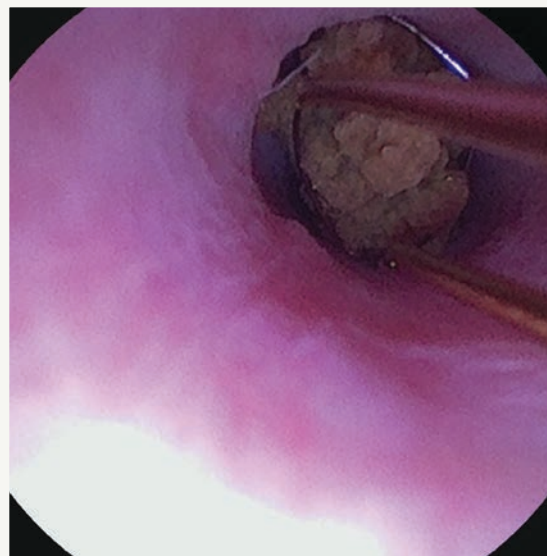


FIGURE 6. Endoscopic image of the patient shown in **FIGURE 1**. The urethrolith has been grasped with a retrieval device and is being withdrawn back into the urinary bladder for removal.

or beagles younger than 3 years).^{15,16} These individuals have a mutation affecting the *SLC12A1* gene resulting in complex changes in renal electrolyte and acid–base handling.

Water Intake

The most useful way to mitigate stone formation is by increasing water intake. For this reason, a canned diet is always preferable to dry food in CaOx stone-forming dogs. Alternatively, kibble may be soaked in an equal volume of water. Additional strategies include adding a little ultra-low-sodium broth or whipping cream to flavor the water. The authors routinely recommend Purina Hydra Care, as many dogs seem to regard this as a treat.

Nutritional Management

Diet is another key element of stone prevention. Various prescription diets are formulated to produce urine below the RSS for CaOx, and some also address other metabolic issues such as obesity or hyperlipidemia. Some diets are supplemented with salt to increase thirst; this has been shown to decrease urine RSS in healthy dogs, but there is concern that excess dietary sodium may exacerbate calciuria in stone-forming individuals.²⁰ The authors therefore do not recommend feeding a diet with a sodium content > 120 mg/100 kcal. High-protein foods should be avoided, along with those containing substantial amounts of oxalate.²⁵

Medical Therapy

Unfortunately, many dogs continue to form CaOx stones despite excellent dietary compliance, and additional therapies are needed.

Potassium citrate is routinely recommended in patients with persistently acidic urine²⁰ and has been shown to mitigate stone recurrence in humans with hypocitraturia. There are limited data regarding its efficacy in stone-forming dogs, although it has 2 potential benefits: it increases urine pH, and it provides a soluble anion to capture calcium ions and reduce CaOx crystal formation. The starting dose is 75 mg/kg PO q12h.

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Thiazide diuretics increase calcium reabsorption from the glomerular filtrate. Hydrochlorothiazide (2 mg/kg PO q12h) has shown to reduce 24-hour calcium excretion in dogs with a history of CaOx stones.²⁶ This drug also has the advantage of increasing urine output and water intake. Patients should be screened for preexisting hypercalcemia, as this may be exacerbated by a thiazide diuretic.

Supplements

Owners of dogs with recurrent CaOx urolithiasis often seek out supplements and alternative dietary choices and may need guidance to avoid inappropriate interventions.

Zucchini. In 1 small study in healthy cats, the addition of 50 g/kg of fresh diced zucchini decreased urine RSS and raised pH.²⁷ The effects of zucchini have not been reported in dogs, but it appears to be harmless and is usually well tolerated.

Apple cider vinegar. Various studies in humans suggest that daily consumption of vinegar may reduce CaOx nephrolithiasis, potentially enhancing citraturia and reducing calciuria.²⁸ Some of the authors' clients routinely administer a daily dose of 5 mL of raw, unfiltered organic apple cider vinegar that contains the mother, diluted in 60 mL of water and sweetened with a dash of honey, to their refractory stone-forming dogs.

Vitamin B₆. Pyridoxine reduces hyperoxaluria in a subgroup of human CaOx stone formers with a specific genetic disorder. However, there is minimal evidence to support its use in canine patients consuming a balanced diet.

Cranberry extract. There is equivocal evidence that cranberry juice may help prevent recurrent UTI in humans, and cranberry extracts are widely touted to improve urinary tract health. However, cranberry extract has been shown to increase urinary oxalate in humans²⁹ and should not be administered to CaOx stone-forming dogs.

Monitoring

Urine Characteristics

Urine pH and specific gravity should be monitored regularly, with target values of 6.5 to 7.5 and <1.020, respectively.²⁰ However, urine pH varies substantially over the course of the day, with substantial increases noted several hours after a meal. A one-off in-clinic value may therefore be a poor reflection of actual events. In addition, urine dipstick pH readings lack accuracy and may overreport the actual value. The authors recommend a urinalysis 2 weeks after any change in diet or medications and then at least quarterly. Motivated owners should be encouraged to purchase an inexpensive handheld pH measuring device and check urine 2 to 3 times a week.

The authors do not routinely measure urine calcium:creatinine ratios in patients with a history of urolithiasis. Values are usually higher in CaOx stone formers than in normal dogs but do not appear to be consistently predictive of stone recurrence.^{10,30}

However, an increased urine calcium:creatinine ratio may identify individuals at risk of stone formation, and measurement should be preemptively considered in young adults of high-risk breeds.

Imaging

Quarterly or biannual ultrasonography is recommended for dogs with a history of nephrolithiasis or ureterolithiasis.

Abdominal radiography with a spoon view should be performed 3 months after cystotomy for stone removal. Usually, if new stones have formed, they should still be small enough for removal via VUH or cystoscopy. If the dog is still stone-free at the 6-month recheck, subsequent rechecks can be biannual.

Summary

The prevalence of CaOx urolithiasis in dogs appears to be rising, and practitioners need to be prepared to promptly identify affected patients and create appropriate treatment plans. Owners need to understand that stone removal is not the end of the story and that ongoing management is needed to prevent recurrence. **TVP**

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CE Quiz Questions

1. Which of the following breeds is predisposed to calcium oxalate (CaOx) urolithiasis?
 - a. Miniature schnauzer
 - b. German shepherd
 - c. Scottish deerhound
 - d. Labrador retriever
2. Hydrochlorothiazide is routinely prescribed for the prevention of CaOx stones. What is its mechanism of action?
 - a. Increased sodium uptake in the proximal convoluted tubule
 - b. Decreased oxalate excretion in urine
 - c. Decreased calciuria
 - d. Decreased uptake of dietary oxalate
3. Ureteral relaxants are often administered along with fluid therapy and pain management to encourage the passage of an obstructive ureterolith. Which of the following drugs is thought to decrease ureteral tone?
 - a. Prazosin
 - b. Propranolol
 - c. Phenylpropanolamine
 - d. Glucagon
4. A 7-kg (15.4-lb) female spayed terrier with a history of CaOx urolithiasis presents with mild pollakiuria and is found to have four 3-mm cystoliths. What is the most appropriate treatment option for this patient?
 - a. Carprofen
 - b. Voiding urohydropropulsion
 - c. Cystotomy
 - d. Potassium citrate
5. Which of the following products should not be administered to a dog with a history of CaOx urolithiasis?
 - a. Cranberry extract
 - b. Zucchini
 - c. Potassium citrate
 - d. Ultra-low-sodium broth

Dr. Cook is a graduate of the University of Edinburgh and completed an internship at North Carolina State University and a residency in small animal internal medicine at the University of California, Davis. She is a diplomate of both the American College of Veterinary Internal Medicine and European College of Veterinary Internal Medicine and is recognized as a specialist in feline practice by the American Board of Veterinary Practitioners. Dr. Cook is a professor at Texas A&M University and is chief of the interventional radiology and endoscopy service, where much of her time is spent managing patients with urinary tract disorders.



Dr. Atiee is a graduate of Texas A&M University and completed an internship and residency in small animal internal medicine at the North Carolina State University College of Veterinary Medicine. She is a diplomate of the American College of Veterinary Internal Medicine and is fellowship trained in interventional radiology. Dr. Atiee is currently a clinical assistant professor at Texas A&M with assignments to both the internal medicine and interventional radiology and endoscopy services. Her professional interests include vascular and urinary interventions and the management of chronic kidney disease and urinary tract infections.

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