Uroliths are concretions composed primarily of highly organized crystalloids and a small amount of organic matrix. They are identified based on their mineral composition: calcium oxalate and struvite (magnesium ammonium phosphate) are the 2 most common feline uroliths.

Feline urine is a complex solution in which salts, such as calcium oxalate and magnesium ammonium phosphate, can remain in solution under conditions of supersaturation. This urine does, however, have a potential energy for precipitation, or the tendency to form crystals from dissolved salts. When crystals aggregate and grow into calculi before being voided, uroliths form.

Feline uroliths form in the urinary bladder (most commonly) or renal pelvis. They are most commonly found in the urinary bladder and urethra but may also be located in the kidneys and ureters. Urolithiasis may affect as many as 25% of cats with lower urinary tract disease.1

PATHOPHYSIOLOGY

Struvite Uroliths

In cats, approximately 45% of uroliths consist entirely or predominantly of struvite, and most feline struvite uroliths form in sterile urine (Figure 1).1 The pathophysiology of struvite urolith formation in sterile urine is poorly understood; however, dietary and metabolic factors that result in alkaline urine and increased concentrations of magnesium, ammonium, and phosphate in urine have been implicated.

Dietary Factors. Diets high in magnesium, phosphorus, sodium, chloride, and fiber, with moderate protein content have been associated with increased risk.2 A greater ability to concentrate urine (compared with dogs, in which struvite uroliths are commonly associated with infection) and, therefore, greater urine supersaturation, may be partially responsible for urolith formation in cats without urinary tract infections (UTIs).

Metabolic Factors. In addition, formation of sterile struvite uroliths may be twice as likely if urine pH is consistently elevated (6.5–6.9 versus 6–6.2).2 Alkaline urine pH is commonly affected by diet but may also be associated with drug therapy and renal tubular disorders. In 1981, more than 80% of the feline uroliths analyzed at the Minnesota Urolith Center were struvite.3 A major factor contributing to the decline in feline struvite uroliths over the last 35 years is the widespread use of magnesium-restricted, acidifying diets.

Infection. Struvite uroliths in cats may be associated with UTI, especially when caused by bacteria that produce urease, such as Staphylococcus and Proteus species. In such cases, urease increases the ammonium concentration in urine, resulting in an increase in urine pH and a change in the ionization state of phosphorus. Interestingly, struvite uroliths associated with UTI tend to be more radiodense than struvite uroliths that form in sterile urine.4

Calcium Oxalate Uroliths

Factors involved in the pathogenesis of calcium oxalate urolithiasis (Figure 2, page 16) in cats are not completely understood but involve urine supersaturation with calcium and oxalate:

• Increased dietary intake or endogenous production of oxalate may result in hyperoxaluria.
• Metabolism of vitamin C, glycine, and glyoxylate can increase production and excretion of oxalate.
• Enteric oxalate absorption may actually increase if (1) dietary intake of calcium is low and (2) less oxalate in the gut is complexed with calcium.
• Hypercalciuria may result from overt hypercalcemia (eg, idiopathic hypercalcemia, parathyroid adenocarcinoma).5 Ionized calcium concentrations should be measured in cats with calcium oxalate uroliths to rule out hypercalcemia.
• Decreased concentrations of calcium oxalate crystallization inhibitors (eg, citrate, magnesium, nephrocalcin, and osteopontin) may contribute to calcium oxalate urolith formation.

Dietary & Metabolic Factors. As with struvite uroliths, diet can also influence the development
of calcium oxalate uroliths. Cats fed low-sodium or low-potassium diets or diets formulated to maximize urine acidity are at increased risk.2,6

In 1981, less than 10% of the feline uroliths analyzed at the Minnesota Urolith Center were calcium oxalate; in 2013, that percentage had increased to 41%.3 Use of acidifying diets is thought to have played a role in this increase: diets that produce a urine pH between 6 and 6.2 are 3 times more likely to produce calcium oxalate uroliths when compared with acidifying diets designed to produce a urine pH between 6.5 and 6.9.2

In addition, metabolic acidosis increases calcium mobilization from bone and contributes to hypercalciuria as well as decreased urinary citrate excretion.

RISK FACTORS

Struvite Uroliths
- **Age:** Peak incidence of struvite uroliths in cats appears to be between 2 and 7 years of age.1
- **Sex:** Female cats appear to have increased risk for struvite urolithiasis.7,10
- **Breed:** Breeds reported to have decreased risk for struvite uroliths include Burmese, Persian, Himalayan, Rex, Abyssinian, Russian blue, Birman, and Siamese.7,8 However, one study found Siamese cats to be at increased risk for struvite uroliths.10
- **Concurrent infection:** Infection-associated struvite uroliths are more common in kittens and older female cats. Risk factors for UTI in cats include female sex, Persian breed, increasing age, decreasing body weight, chronic kidney disease (CKD), hyperthyroidism, and diabetes mellitus.11

Calcium Oxalate Uroliths
- **Age:** Older cats (8–12 years) are most commonly affected by calcium oxalate uroliths.
- **Sex:** Male cats most commonly develop calcium oxalate uroliths.7-10
- **Breed:** Male domestic short-haired, medium-haired, and long-haired cats appear to be 1.4 times more likely to develop a calcium oxalate urolith than a struvite urolith, while both male and female purebred cats (eg, Persian, Himalayan, Burmese, ragdoll cats) appear to be at risk.9
- **Concurrent conditions:** While concurrent UTI appears to be rare in cats with calcium oxalate uroliths, many cats with CKD also have calcium oxalate nephroliths.

Recurrence of calcium oxalate uroliths in cats is a potential problem. In a study of more than 2000 cats with calcium oxalate uroliths, 7% had a first recurrence, 0.6% had a second recurrence, and 0.1% had a third recurrence.12 These results underscore the need for medical protocols aimed at decreasing recurrence of calcium oxalate uroliths after urolith removal.

FIGURE 1. Lateral radiograph of a 6-year-old spayed female domestic shorthair cat with multiple struvite cystoliths (A); 80% struvite, 20% ammonium acid urate cystoliths were removed from this cat (B). (Scale, 1 division = 1 mm)
CLINICAL SIGNS

Clinical signs of urolithiasis in cats depend on urolith number, location, and physical characteristics. Solitary, smooth uroliths in the bladder or renal pelvis may be less irritating than multiple uroliths or uroliths with irregular or sharp borders. Urolithiasis complicated by bacterial UTI is more likely to cause tissue inflammation than sterile urolithiasis.

Nephroliths

Nephroliths are often asymptomatic but can be associated with microscopic or gross hematuria. All nephroliths have potential to damage renal tissue and cause chronic inflammation; this chronic inflammation may decrease normal host defense mechanisms and increase the risk for ascending bacterial pyelonephritis in cats with lower UTIs.

Larger nephroliths can cause hydronephrosis associated with pelvic and/or ureteral obstruction. Smaller nephroliths may pass through the ureter asymptptomatically; however, hydrouréter and hydronephrosis may be secondary to urolith-induced ureteral obstruction or stricture.

Ureteroliths

Ureteroliths may be asymptomatic or associated with varying degrees of abdominal pain and decreased appetite. In cats with pre-existing CKD, partial or complete ureteral obstruction will often result in an “acute-on-chronic” decompensation of renal function that may include hyperkalemia and/or acidemia. Ureteral obstruction in a cat with previously normal renal function may not be associated with any clinicopathologic abnormalities, especially if it is unilateral, but renal asymmetry may be palpated due to hydronephrosis.

Cystoliths

Cystoliths may be asymptomatic or, instead, irritate the uroepithelium, resulting in hematuria, pollakiuria, and dysuria/stranguria. Struvite cystoliths can result from urease-producing bacterial UTI; however, any urocystolith can irritate the uroepithelium, compromise host defense mechanisms, and predispose the patient to a complicated bacterial UTI.

Urethral Uroliths

Urethral uroliths are common causes of partial or complete urethral obstruction in males, leading to an altered or absent urine stream, hematuria, or dysuria/stranguria. In cases of complete urethral obstruction, postrenal azotemia and uremia develop within 24 to 36 hours.

DIAGNOSIS

Imaging

The number, mineral composition, size, and location in the urinary tract affect the radiographic and ultrasonographic appearance of uroliths.

• Calcium oxalate uroliths are typically the most radio-opaque of all uroliths, and usually are easily observed on plain film radiographs.
• Struvite uroliths are less radio-opaque than calcium oxalate uroliths.
• Small uroliths (< 3 mm) of any composition may be difficult to visualize on survey radiographs.
• Calcium oxalate nephroliths can be difficult to differentiate from renal soft tissue mineralization on survey radiographs.

Indications for imaging besides radiography include:
• Ultrasonography: For detection of radiolucent uroliths, as well as obstructive uropathy resulting in renal pelvic or ureteral dilatation (Figure 3).
• Combination of radiography and ultrasonography: Recommended to diagnose...
nephroliths and ureteroliths (Figure 3). Ultrasonography can also be used to document renal pelvic dilation (pyelectasia) (Figure 4) and ureteral dilation in cases of ureteral obstruction.

- **Double-contrast cystography:** Affords increased sensitivity for detecting small or radiolucent uroliths (usually not necessary for calcium oxalate and struvite urolithiasis).

- **Intravenous urography and ultrasonography:** May be used to detect radiolucent nephroliths and differentiate mineralized renal tissue from actual nephroliths. Intravenous urography can also be used to document ureteral obstruction.

- **Ultrasound-guided antegrade pyelography:** To document ureteral obstruction (Figure 5).

**Cystoscopy**

Transurethral cystoscopy may be performed in both male (flexible scope) and female (rigid scope) cats for the diagnosis of cystoliths; however, general anesthesia is required. In female cats, holmium:YAG laser lithotripsy associated with cystoscopy may be used to noninvasively “break up” cystoliths and remove them from the bladder without surgery. Cystoscopy may also be used to obtain biopsy tissue from the lower urinary tract.

**Laboratory Findings**

Urine pH, crystalluria, and presence of urease-producing bacteria may aid in the presumptive identification of urolith type. Serum ionized calcium concentrations should be assessed in cases of suspected calcium oxalate uroliths to rule out hypercalcemia.

Uroliths may be caused by a UTI (struvite) or may compromise normal host defense mechanisms and predispose cats (especially female cats) to UTI. Therefore, a urine culture should be routinely performed.

**Definitive Diagnosis**

Definitive diagnosis requires quantitative mineral analysis of uroliths that have been voided or recovered from the urinary tract.

**TREATMENT**

General principles for treatment of urethral calculi include relief of urethral obstruction and bladder decompression, if necessary, which can usually be accomplished by:

- Passage of a small-bore catheter
- Cystocentesis
- Dislodgment of urethral calculi by hydropropulsion.

Fluid therapy should be initiated to restore water and electrolyte balance, if postrenal azotemia exists.

**Surgical Therapy**

Surgical intervention for calcium oxalate nephroliths (beyond dietary treatment—see Calcium Oxalate Uroliths, page 19—to help slow urolith growth) is usually not recommended. Similarly, surgical intervention of ureteral uroliths is usually not
recommended. In both cases, the complication rate associated with surgery (eg, compromised renal function and ureteral stricture) is high.

Cats with obstructive ureterolithiasis are best managed with ureteral stents or subcutaneous ureteral bypass (SUB). Intracorporeal laser lithotripsy via cystoscopy may be used to treat cystoliths in female cats.

Emergent Therapy
Hyperkalemia is a potentially life-threatening electrolyte disturbance that may occur in cats with postrenal azotemia caused by urethral obstruction or rupture of the urinary bladder or urethra. In cats suspected of having urethral obstruction, findings that suggest hyperkalemia include:

- Elevated serum potassium, blood urea nitrogen, and creatinine concentrations
- Bradycardia and electrocardiographic findings of flattened P waves, a prolonged PR interval, widened QRS complexes, and tall or spiked T waves.

These findings indicate the need for emergency treatment to decrease the serum potassium concentration prior to sedation/anesthesia for urethral catheterization.

Struvite Uroliths
Medical dissolution of feline struvite uroliths is effective; however, the decision to proceed surgically as opposed to medically involves several considerations (Table 1).

Diet. Struvite dissolution diets (Table 2) are magnesium-reduced, acidifying diets. Due to their high sodium content and acidifying nature, these diets should not be fed to immature cats; reproducing queens; or cats with CKD, hypertension, congestive heart failure, postrenal azotemia/uremia, or hypokalemia. Additional supplementation of sodium chloride and/or urinary acidifiers is not recommended with use of dissolution diets.

It is ideal to transition from the normal diet to the dissolution diet over a period of at least 1 week. Reradiograph cats on dissolution diets every 2 to 4 weeks, and feed the diet for a minimum of 30 days after the uroliths are no longer visible radiographically. The rate at which uroliths dissolve is proportional to the surface area of the urolith exposed to the undersaturated urine. Small, sterile struvite uroliths may dissolve in as little as 1 to 2 weeks.\footnote{14}

Struvite dissolution diets do not dissolve nonstruvite uroliths and are less effective if a persistent UTI is present or the cat is fed anything in addition to the dissolution diet.\footnote{14,15}

\begin{table}[h]
\centering
\caption{Medical Versus Surgical Treatment for Struvite Urolithiasis}
\label{table:medical_surgical}
\begin{tabular}{|l|l|}
\hline
\textbf{ADVANTAGES} & \textbf{DISADVANTAGES} \\
\hline
\textbf{Surgical} & \\
\hline
- Allows definitive diagnosis of urolith type via quantitative analysis & - Requires anesthesia \\
- Allows surgeon to correct any concurrent or predisposing anatomic abnormalities (eg, urachal remnants, urinary bladder polyps) & - Surgery is invasive, with potential for complications \\
- Enables collection of urinary bladder mucosal samples for bacterial culture if urine yields no growth on culture & - Associated with possible incomplete urolith removal \\
- Enables collection of urinary bladder mucosal samples for bacterial culture if urine yields no growth on culture & - Often associated with persisting underlying causes; therefore, recurrence is likely and medical management still necessary \\
\hline
\textbf{Medical} & \\
\hline
- Lower initial costs & - Total cost similar to that of surgical treatment due to involved follow-up protocol \\
- Noninvasive & - Follow-up frequently involves urinalyses, bacterial cultures (if uroliths associated with bacterial UTI), and imaging \\
- Lower complication rate & - Considerable owner compliance required for several weeks to months during follow-up \\
\hline
\end{tabular}
\end{table}

\begin{table}[h]
\centering
\caption{Examples of Feline Struvite Dissolution Diets}
\label{table:dissolution_diets}
\begin{tabular}{|l|}
\hline
Hill’s Prescription Diet s/d Feline (hillsvet.com) \\
Medi-Cal Veterinary Diets Dissolution Formula (Veterinary Medical Diets, Inc, Guelph, Ontario) \\
Purina Veterinary Diets UR Urinary St/Ox Feline Formula (purinaveterinarydiets.com) \\
Royal Canin Veterinary Diet Urinary SO (royalcanin.com) \\
\hline
\end{tabular}
\end{table}
Antibiotics. In addition to decreasing the concentration of crystalloids in urine, elimination of any bacterial UTI is essential in medical treatment of struvite urolithiasis. If infection is present at start of treatment, continue antibiotics throughout the course of medical dissolution because viable bacteria may be released from uroliths as they dissolve. Select antibiotics based on urine culture and sensitivity findings. Infection-induced struvite uroliths usually dissolve in 2 to 3 months.\textsuperscript{15}

Calcium Oxalate Uroliths
Medical dissolution diets for oxalate urolithiasis are not yet available. Small urocystoliths may be removed by catheter retrieval or voiding hydropropulsion in female cats; however, surgery is the usual means for removal of large calcium oxalate cystouroliths.

Some calcium oxalate uroliths, especially nephroliths, may remain clinically quiescent for months to years. Cats with CKD, and with suspected calcium oxalate nephroliths, had no increased risk for kidney disease progression, uremic crises, or death compared with cats with similar stage CKD without nephroliths.\textsuperscript{16} Manage patients with nephroliths with medical protocols designed to prevent or slow calcium oxalate urolith growth (see Prevention), and monitor location and size of the nephroliths several times a year with radiography or ultrasonography.

Acute decompensation of a patient with CKD and known or suspected nephroliths should prompt swift evaluation to rule out an obstructive uropathy.

FOLLOW-UP & MONITORING
\begin{itemize}
\item Use radiography or ultrasonography to ensure complete removal of uroliths.
\item Monitor effects of preventive treatment on urine pH and crystalluria with frequent urinalysis (every 2–4 weeks).
\item In cases of new or continued hematuria, pyuria, or bacteriuria, use urine culture and sensitivity and survey abdominal radiography or ultrasonography to assess the urinary tract.
\end{itemize}

PREVENTION
Struvite Uroliths
Measures to prevent struvite urolith recurrence include preventing and controlling UTIs in cases of infection-induced struvite uroliths, maintaining acidic urine, and decreasing dietary intake of magnesium. Numerous struvite prevention maintenance diets are available commercially (Table 3).

<table>
<thead>
<tr>
<th>TABLE 3. Examples of Feline Struvite Prevention Diets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hill’s Prescription Diet c/d Multicare Feline Bladder Health (hillsvet.com)</td>
</tr>
<tr>
<td>Iams Veterinary Formula Urinary-S Plus Low pH/S (iamsvetformula.com)</td>
</tr>
<tr>
<td>Medi-Cal Veterinary Diets Feline Preventive Formula (Veterinary Medical Diets, Inc, Guelph, Ontario)</td>
</tr>
<tr>
<td>Purina Veterinary Diets UR Urinary St/Ox Feline Formula (purinaveterinarydiets.com)</td>
</tr>
<tr>
<td>Royal Canin Veterinary Diet Urinary SO (royalcanin.com)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 4. Examples of Feline Calcium Oxalate Prevention Diets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hill’s Prescription Diet c/d Multicare Feline Bladder Health (hillsvet.com)</td>
</tr>
<tr>
<td>Iams Veterinary Formula Urinary O–Moderate pH/O (iamsvetformula.com)</td>
</tr>
<tr>
<td>Medi-Cal Urinary SO (Veterinary Medical Diets, Inc, Guelph, Ontario)</td>
</tr>
<tr>
<td>Purina Veterinary Diets UR Urinary St/Ox Feline Formula (purinaveterinarydiets.com)</td>
</tr>
<tr>
<td>Royal Canin Veterinary Diet Urinary SO (royalcanin.com)</td>
</tr>
</tbody>
</table>
**Calcium Oxalate Uroliths**

Several commercially available diets have been specifically formulated to prevent recurrence of calcium oxalate uroliths in cats (Table 4, page 19). Canned diets are usually recommended over dry diets because of their high water content.

**Dietary Restrictions.** Moderate restriction of calcium, oxalate, sodium, and potassium intake in association with normal intake of phosphorus and mild increases in magnesium is recommended to prevent recurrence of calcium oxalate uroliths after surgical removal. Increased dietary sodium intake may result in an increase in urinary excretion of calcium and, therefore, should be avoided. Feeding human foods with high calcium or oxalate content (eg, chocolate, peanuts, beets, sweet potatoes, spinach, rhubarb) should also be avoided.

**Potassium Citrate.** Oral potassium citrate may help prevent recurrence of calcium oxalate uroliths; citrate complexes with calcium, forming the more soluble calcium citrate in urine. In addition, potassium citrate results in mild urine alkalization, which increases the solubility of calcium oxalate. However, avoid overzealous urine alkalization because it may result in formation of calcium phosphate uroliths.

Urine alkalization is indicated if urine pH is consistently lower than 6.5. Titrate potassium citrate to produce an ideal target urine pH of 7 to 7.5. The recommended starting dose of potassium citrate is 50 to 75 mg/kg PO Q 12 H.

**Diuretics.** Use of thiazide diuretics to decrease urinary excretion of calcium in cats with recurrent calcium oxalate urolithiasis is controversial. In healthy young female cats, use of hydrochlorothiazide was associated with lower urinary calcium oxalate saturation but there was no difference in 24-hour urine calcium excretion. The authors of that study cautioned against extrapolating the results to cats with recurrent calcium oxalate urolithiasis.

**CKD = chronic kidney disease; SUB = subcutaneous ureteral bypass; UTI = urinary tract infection**

*FIGURE CREDIT*


**References**


