Canine Struvite Urolithiasis

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**ABSTRACT:** Struvite is the most common canine urolith. Struvite uroliths form when urine is supersaturated with magnesium, ammonium, and phosphate. Saturation is usually associated with a bacterial urinary tract infection (UTI) with urease-producing bacteria such as *Staphylococcus* species or, less commonly, *Proteus* species. Infections are particularly common in female and young dogs. Medical dissolution of struvite is best achieved with a combination of a struvitolytic diet and antibiotics chosen by culture and sensitivity. These treatments should continue for at least 1 month past survey radiographic resolution of uroliths. Prevention or early eradication of bacterial UTI is the most important preventive measure for infection-induced struvite uroliths in dogs.

Struvite uroliths are composed of magnesium ammonium phosphate hexahydrate. A Swedish geologist coined the term *struvite* in 1845 to honor H.C.G. Struve, a Russian diplomat and naturalist. Struvite has also been called triple phosphate; however, this is a misnomer, reflecting historical confusion about the mineral composition of the stone based on qualitative instead of quantitative analysis.

**ETIOPATHOGENESIS**

An important cause of urolith formation is supersaturation of urine with calculogenic substances. For struvite uroliths to form, urine must contain increased concentrations of magnesium, ammonium, and phosphate ions. In dogs, most struvite uroliths are associated with a bacterial urinary tract infection (UTI) with urease-producing bacteria such as *Staphylococcus* species or, less commonly, *Proteus* species (Figure 1). Occasionally, urease may be produced by *Streptococcus* or *Klebsiella* species or, rarely, by *Escherichia coli*; but these organisms have rarely been associated with struvite uroliths. Urease is an enzyme that, in the presence of water, metabolizes urea to ammonia and carbon dioxide, resulting in increased levels of ammonia in urine. Ammonia combines with water or hydrogen ion to produce ammonium ion (NH$_4^+$). Buffering of hydrogen ion by ammonia results in increased urinary pH and a shift of phosphorus from H$_3$PO$_4^-$ to PO$_4^{3-}$. With increased levels of NH$_4^+$ and PO$_4^{3-}$ in the presence of Mg$^{2+}$ and an alkaline pH, the solubility product and formation product of struvite may be exceeded, resulting in precipitation. In addition, damage to bladder epithelium by bacteria and their metabolic byproducts may provide a surface on which struvite can pre-
An increased risk of forming struvite uroliths is seen in some breeds, though uncommon, the presence of carbonate apatite may also precipitate with struvite. Alkaluria and carbon dioxide in the urine can hinder medical dissolution of struvite uroliths.

In one analysis of canine renal calculi, 29% were struvite; 24% were calcium oxalate; 11% were ammonium urate; 6% were calcium apatite; and 1% each were calcium hydroxyapatite, sodium urate, silica, and xanthine. The other 25% of these nephroliths were of mixed composition with no one predominant mineral type. More recent reviews of canine renal calculi found that 57% of 317 specimens contained a mixture of mineral types and 41% of 797 nephroliths were calcium oxalate and 33% were struvite. Struvite nephroliths are associated with bacterial UTIs in over 80% of cases.

PREVALENCE

Although the relative prevalence of different types of canine uroliths has changed over the past 10 years, struvite remains the most common canine urolith type submitted to the Minnesota Urolith Center, St. Paul, MN. Struvite constituted 50% of canine uroliths and 33% of canine nephroliths from 1981 to 1997. The majority (95%) of struvite uroliths occur in the lower urinary tract. Stones vary in size, shape, and texture (Figure 2). The size and shape of struvite uroliths may also change rapidly or remain static over a period of years. Struvite uroliths have been documented to begin forming within 2 to 8 weeks following infection with urease-producing Staphylococcus species. Although size and shape vary within each mineral type, there are some similarities. Urocystoliths over 10 mm in diameter are more than 92% likely to be struvite. Urocystoliths that are smooth, faceted, or pyramidal are usually struvite (Figure 2), but smooth uroliths can also be cystine, ammonium urate, or calcium oxalate monohydrate. Jackstone configurations are most consistent with silica, and grape clusters (botryoidal stones) are usually calcium oxalate.

The mean age at which struvite stones are removed is 6.0 ± 2.9 years (range, 1 month to 19 years). Female dogs are more commonly affected than males. Of uroliths in females, 88% were struvite versus 38% in males. This may be related to the greater propensity for females to develop bacterial UTIs. Females are also more likely to form stones of mixed mineral type than males. Infection-induced struvite is also the most common mineral component of uroliths retrieved and analyzed from dogs younger than 1 year of age. Although any breed may be affected, miniature schnauzers, shih tzus, bichon frises, miniatures, Pomeranians, Maltese) have a relatively decreased risk of forming struvite uroliths compared with other mineral types. Struvite uroliths are occasionally formed in dogs in the absence of urease-producing bacteria. The etiopathogenesis and biologic behavior of these sterile struvite uroliths are different from those of infection-induced struvite uroliths in dogs but similar to those of sterile struvite uroliths in cats. Renal tubular acidosis results in alkaluria and could therefore theoretically contribute to the formation of struvite uroliths. None of the dogs in one study had renal tubular acidosis. However, renal tubular acidosis was found in several related dogs affected with sterile struvite uroliths. In these dogs, uroliths were highly recurrent and successfully prevented by feeding a diet with added acidifiers or by administering a urinary acidifier.

Figure 1—Diagrammatic representation of the formation of magnesium ammonium phosphate hexahydrate (struvite) crystals secondary to a urease-producing bacterial urinary tract infection.
70% of cases. However, the presence of a bacterial UTI alone does not guarantee that the nephrolith will be struvite. Approximately 50% of dogs with calcium oxalate nephroliths also have bacterial UTIs that may or may not produce urease. Female dogs are at a higher risk of developing struvite nephroliths than are male dogs. Male dogs have a higher prevalence of calcium oxalate nephroliths, which may be related to the higher rate of concurrent bacterial UTIs in female dogs with renal calculi. Urease-producing bacteria may contribute to renal struvite formation, but any bacteria may opportunistically cause infection due to altered defense mechanisms in the urinary tract after any type of stone has formed.

**CLINICAL PRESENTATION**

Most dogs with struvite urolithiasis have cystoliths associated with a bacterial UTI; therefore, clinical signs will reflect lower urinary tract inflammation and infection. Owners may report pollakiuria, dysuria, stranguria, and/or hematuria. Dogs (especially males) will occasionally present with partial or complete urethral obstruction. Also, hydronephrosis or pyelonephritis may occur. Processes that increase the risk of bacterial UTI may increase risk of struvite formation (see Case Examples, pp. 410 and 411).

Alkaluria (pH greater than 7.0) is usually detected on urinalysis. There may be pyuria, hematuria, bacteruria, and/or struvite crystalluria. Presence of struvite crystalluria in a fresh urine specimen implies that the urine is supersaturated with magnesium, ammonium, and phosphate (Figure 3). The presence of struvite crystalluria does not necessarily indicate that struvite uroliths are present. However, during the process of medical dissolution therapy, the presence of struvite crystalluria does suggest that therapy has not been effective in promoting the formation of urine undersaturated with magnesium, ammonium, and phosphate. Serum biochemical analysis may be abnormal if the animal has any concurrent diseases (e.g., diabetes mellitus, hyperadrenocorticism) or if bilateral pyelonephritis or hydronephrosis is present.

Survey abdominal radiographs are a very accurate method for detecting the presence of struvite uroliths that are over 3 mm in diameter (Figure 4). The false-negative detection rate for struvite uroliths by survey radiographs according to in vitro studies is reportedly only 2%. Pneumocystography may increase diagnostic accuracy, particularly with regard to the number of cystoliths present. Double-contrast cystography is more sensitive than either survey radiography or pneumocystography for detecting the presence and number of cystoliths, with a false-negative detection rate of 5% for all cystoliths and 0% for struvite cystoliths according to in
Case Example #1

**Signalment:** 3-year-old, spayed collie cross

**History:** Signs of lower urinary tract disease (stranguria, pollakiuria, hematuria) for 2 weeks; no other history of medical problems

**Physical examination:** No abnormalities were found.

**Results of diagnostic evaluation:** Findings on urinalysis included evidence of a bacterial urinary tract infection (UTI) with inflammation (pH, 8.0; red blood cells [RBCs] too numerous to count per high-power field [HPF]; 50 to 100 white blood cells [WBCs] per HPF; large numbers of cocci/HPF; 4+ proteinuria; 4+ occult blood) and struvite crystalluria. *Staphylococcus intermedia* (>100,000 cfu/ml) were isolated by aerobic bacterial culture of urine collected by cystocentesis. Two relatively large radiodense, smooth mineral densities in the urinary bladder were visible on survey abdominal radiography (A, see below).

**Interpretation and treatment:** A presumptive diagnosis of infection-induced struvite urocystolithiasis was made based on radiography, urinalysis, and aerobic bacterial urine culture. The dog was fed a struvite dissolution diet and treated with amoxicillin–clavulanic acid (22 mg/kg PO q12h for 2 weeks). At examination 4 weeks after initiation of struvitolytic treatment, persistent infection with *S. intermedia* was documented. The urocystoliths were unchanged in size, shape, and number.

**Plans:** Possible explanations for unsuccessful urocystolith dissolution include inappropriate treatment, lack of compliance by owners or patients, and nonstruvite urocystolith composition. Because antibiotics had been discontinued after 2 weeks of treatment, and based on results of current urinalysis, aerobic bacterial urine culture, and abdominal radiography, it was believed that inappropriate duration of treatment had been recommended. (Treatment recommendations included continuing with the struvitolytic diet and amoxicillin–clavulanic acid [22 mg/kg PO q12h] until radiographic evidence of urocystolith dissolution.)

**Follow-up:** One month after re-initiation of struvite dissolution treatment, the urocystoliths were smaller and the urine was acidic (pH, 6.0) with no evidence of infection or inflammation (occult blood and protein were negative, 3 to 5 RBCs/HPF, 0 to 1 WBCs/HPF, no bacteria observed). No bacteria were isolated from an aerobic urine culture. After 2 months of dissolution treatment, urocystoliths were not visible by survey abdominal radiography (B, see below). Urinalysis revealed lack of infection and inflammation; aerobic bacterial urine culture revealed no growth of bacteria. Struvitolytic treatment was continued for 1 additional month and then discontinued. Urocystoliths did not recur over the following 36 months.

**Discussion:** This case is an example of inappropriate treatment for infection-induced struvite urocystoliths in a dog. Because bacteria can be trapped within the matrix of a urolith, it is important to administer appropriate antimicrobial treatment throughout dissolution treatment of struvite uroliths.

(A) Lateral abdominal radiograph of a 3-year-old, spayed collie cross with two urocystoliths presumed to be composed of struvite. This dog also had a *Staphylococcus intermedia* UTI. (B) Lateral abdominal radiograph of the same dog after 2 months of struvite dissolution therapy. Urocystoliths are not observed.
vitro studies. Ultrasonography has not proven more accurate than double-contrast cystography for detection of the presence or number of cystoliths.13

MEDICAL MANAGEMENT
Spontaneous dissolution of struvite uroliths is unusual but has been reported.14,15 Most struvite uroliths require medical therapy for dissolution. Medical management is effective for struvite cystoliths; however, ureteroliths and urethroliths are not amenable to medical management. They are not consistently in contact with undersaturated urine and are not highly affected by changes in urine composition.

Medical dissolution of struvite nephroliths with a cal-
culolytic diet and antibiotics has been reported in six dogs.\textsuperscript{10} Duration of therapy ranged from 67 to 300 days (mean, 184 days). These dogs had concurrent bacterial pyelonephritis and impaired urine-concentrating ability. During dissolution, as nephroliths become smaller, they may pass into ureters and cause obstruction and hydronephrosis, but this is uncommon. Therefore, medical dissolution of struvite nephroliths requires radiographic reevaluation every 1 to 4 months to detect ureteroliths before they cause significant hydronephrosis.

**Antibiotics**

Antibiotics are an essential component of treating infection-induced struvite uroliths. Treatment should include therapeutic doses of antimicrobial drugs selected with the aid of susceptibility testing. The ideal antimicrobial would be bactericidal, achieve high concentrations in urine, and be associated with few adverse reactions or side effects.

Antibiotic treatment needs to be continued as long as uroliths remain in the urinary tract. Even if the urine quickly becomes sterile, bacteria may remain viable within the matrix of a urolith and become exposed to the urine as the urolith dissolves. Struvitolytic diets and antibiotic therapy need to continue at least 1 month beyond survey abdominal radiographic evidence of urolith dissolution. This reduces the likelihood of recurrence of clinical signs due to regrowth of small (less than 3-mm diameter) uroliths that are not detectable radiographically.\textsuperscript{1}

**Diet**

Antibiotic therapy alone is rarely sufficient to dissolve struvite urolithiasis. Dietary therapy may aid dissolution by increasing urine volume and decreasing urine concentrations of urea, phosphorus, and magnesium. A high-moisture struvitolytic diet (Hill’s\textsuperscript{®} Prescription Diet\textsuperscript{®} Canine s/d\textsuperscript{®}, Hill’s Pet Nutrition, Inc., Topeka, KS) has been specially formulated to contain low quantities of high-quality protein, phosphorus, and magnesium. This diet also contains supplemental sodium chloride to stimulate water intake and diuresis. Use of this struvitolytic diet in combination with antibiotics hastens the dissolution process. Average dissolution time of infection-induced struvite stones is 8 to 10 weeks, although this varies depending on the number, size, location, and surface area of the uroliths.\textsuperscript{1}

This diet is designed for short-term calculolytic therapy only and has been associated with low serum concentrations of urea, magnesium, phosphorus, and albumin and mild increases in alkaline phosphatase activity. These changes have not been documented to have a detrimental effect during clinical studies. It is inadvisable to put immature animals on the struvitolytic diet for prolonged periods. Blood urea nitrogen concentration in animals consuming the struvitolytic diet can be used to monitor client and patient compliance with dietary therapy.\textsuperscript{16}

The struvitolytic diet is also relatively high in fat; therefore, it is prudent to carefully monitor animals at risk for pancreatitis or those with abnormal lipid metabolism. High fat intake is of particular concern with miniature schnauzers that are predisposed to struvite urolithiasis, abnormalities in lipid metabolism, and pancreatitis. It is also important to avoid glucocorticoid administration to patients undergoing medical dissolution of struvite uroliths. Glucocorticoids will decrease the patient’s ability to clear the bacterial UTI and in-
crease the risk of pancreatitis. Similarly, patients with hyperadrenocorticism or diabetes mellitus are immunosuppressed (and therefore have difficulty clearing UTIs) and are at risk for developing pancreatitis.

The relatively high sodium chloride content of this diet is contraindicated for patients with concurrent hypertension or diseases associated with a positive fluid balance, such as congestive heart failure. Owners should be advised that the high sodium content of the diet and renal medullary depletion of urea will likely cause polyuria and polydipsia. The low protein content of the struvitolytic diet may also produce a catabolic state in animals with azotemic renal failure, particularly if given for a prolonged period of time.

Sterile struvite urocystoliths in dogs can also be dissolved medically. These uroliths develop in some dogs consuming adult maintenance canine diets. They have been successfully dissolved using the struvitolytic diet within 4 weeks of initiation of treatment. No antibiotics were administered because these uroliths are not associated with a bacterial UTI. Sterile struvite uroliths appear to have a high recurrence rate; dogs with these uroliths may require long-term restriction of dietary phosphorus and magnesium. However, restriction of dietary protein may not be necessary for dissolution of sterile struvite uroliths. Acidification of the urine to a pH of approximately 6.0 to 6.5 without dietary restriction may be effective in promoting dissolution.14,16

### Urease Inhibitors

Acetohydroxamic acid (Lithostat®, Mission Pharmaceuticals, San Antonio, TX) is both a competitive and non-competitive inhibitor of bacterial urease.17 This agent decreases struvite formation by decreasing urinary NH₃ and alkalinity by inhibiting hydrolysis of urea but does not affect bacterial viability. At 12.5 mg/kg PO q12h it decreases growth of struvite uroliths and hastens dissolution. Higher doses have been documented to dissolve experimentally induced struvite uroliths without concurrent diet change or antibiotic therapy. However, this dose caused hemolytic anemia, blood dyscrasias, and abnormal bilirubin metabolism and therefore cannot be recommended. Urease inhibitors are not a necessary component of therapy in most cases. However, they may be helpful in cases with very recalcitrant infections. Acetohydroxamic acid cannot be used safely in animals with azotemic renal failure due to decreased drug excretion. It is also teratogenic and should not be given to pregnant animals.17,18

### Urinary Acidification

Urinary acidification is usually accomplished with dietary therapy. Additional acidification is not recom-
mended for animals on a struvitolytic diet as this can cause metabolic acidosis. Urinary acidification without dietary change is not likely to be effective in inducing dissolution of infection-related struvite stones. The production of ammonia by bacterial urease is likely to overwhelm a therapeutic dose of any urinary acidifier.

**SURGICAL MANAGEMENT**

Surgical management of struvite nephrolithiasis is required for stones obstructing the renal pelvis or ureters. Surgery may also be indicated if clinical signs of urocystoliths cannot be controlled or are unacceptable to owners. Patients that have uroliths in several locations within the urinary tract may require medical dissolution postoperatively if stones are not removed from all locations. If uroliths are obstructing the urethra either prior to or during medical dissolution therapy, attempts should be made to dislodge them before surgical intervention. The most common technique is retrograde urohydropropulsion, which can be used to flush the uroliths into the bladder where they can be dissolved medically or removed surgically. This technique has been described elsewhere. Voiding urohydropropulsion may also be used to remove uroliths from the bladder and is particularly effective in cases of smooth uroliths less than 7 to 10 mm in diameter in female dogs and less than 1 to 3 mm in male dogs. This technique has been described elsewhere.

**MONITORING**

Owners should be warned of the potential for urethral obstruction during the process of urocystolith dissolution, especially in male dogs. As stones become smaller, they may pass into the urethra, causing partial or complete obstruction, but this is uncommon. Because female dogs have larger-diameter urethras, they are more likely to pass small uroliths. Ideally, stones lodged in the urethra should be retropulsed into the bladder.

Scheduled reexaminations every 4 weeks are recommended to evaluate safety and efficacy of therapeutic measures (Table 1). A complete urinalysis should be obtained regularly. With effective therapy, struvite crystalluria should be absent, urine pH acidic, and inflammation decreased or resolved. The location, size, and number of remaining uroliths can be monitored with survey radiographs.

Aerobic bacterial urine cultures are an important component of therapeutic monitoring. In an animal without urolithiasis, antibiotic therapy should create sterile urine. However, in the presence of uroliths, antibiotics may only reduce the bacterial colony number. Presence of residual infection does not necessarily prevent dissolution of uroliths. The type of bacteria causing infection may change during the course of therapy, requiring changes in antimicrobial therapy. Reinfection may be due to poor client or patient compliance with antibiotic therapy, urethral catheterization, ascending bacterial infection through the urethra, secondary infection of residual uroliths, or suppression of the dog’s normal host defense mechanisms (see Case Examples, pp. 410 and 411, and Risk Factors for the Development of Struvite Uroliths, p. 417).

**DURATION OF THERAPY**

It is not possible to predict exactly how long it will take to medically dissolve a struvite urolith. Factors involved include the following:

- Whether the struvite uroliths are infected or sterile
- Size, number, and location of uroliths
- Location and quantity of calcium phosphate (if any) mixed with an infection-induced struvite urolith
- Whether the nidus of the urolith(s) is composed of

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**TABLE 1**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Pretherapy</th>
<th>During Therapy</th>
<th>During Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyuria</td>
<td>±</td>
<td>1+ to 3+</td>
<td>None</td>
</tr>
<tr>
<td>Pollakiuria</td>
<td>1+ to 4+</td>
<td>↑ then ↓</td>
<td>None</td>
</tr>
<tr>
<td>Hematuria</td>
<td>1+ to 4+</td>
<td>↓</td>
<td>None</td>
</tr>
<tr>
<td>Urine-specific gravity</td>
<td>Variable</td>
<td>1.004 to 1.014</td>
<td>Variable</td>
</tr>
<tr>
<td>Urine pH</td>
<td>&gt;7.0</td>
<td>&lt;6.5</td>
<td>Variable</td>
</tr>
<tr>
<td>Urinary inflammation</td>
<td>1+ to 4+</td>
<td>↓</td>
<td>None</td>
</tr>
<tr>
<td>Struvite crystalluria</td>
<td>None to 4+</td>
<td>None</td>
<td>Variable</td>
</tr>
<tr>
<td>Bacteriuria</td>
<td>1+ to 4+</td>
<td>↓ to none</td>
<td>None</td>
</tr>
<tr>
<td>Aerobic bacterial culture and sensitivity</td>
<td>Positive</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Blood urea nitrogen (mg/dl)</td>
<td>&gt;15</td>
<td>&lt;10</td>
<td>Variable</td>
</tr>
<tr>
<td>Urolith size and number</td>
<td>Variable</td>
<td>↑</td>
<td>None</td>
</tr>
</tbody>
</table>

19 Voiding urohydropropulsion may also be used to remove uroliths from the bladder and is particularly effective in cases of smooth uroliths less than 7 to 10 mm in diameter in female dogs and less than 1 to 3 mm in male dogs. This technique has been described elsewhere.
a different type of mineral than struvite

Proper selection and administration of antimicrobials

Client and patient compliance with recommendations.

The mean time to dissolution of struvite uroliths in one study was 2 to 3 months, with a range of 2 weeks to 7 months. If struvite uroliths do not dissolve as anticipated, reasons for difficulty should be evaluated (Table 2).

**PREVENTION**

Prevention of or early eradication of a bacterial UTI involving urease-producing microbes is the most important preventive measure for infection-induced struvite

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**TABLE 2**

Managing Refractory Canine Struvite Uroliths

<table>
<thead>
<tr>
<th>Causes</th>
<th>Identification</th>
<th>Therapeutic Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Client-related</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor dietary compliance</td>
<td>Struvite crystalluria, blood urea nitrogen &gt;8–12 mg/dl, urine-specific gravity &gt;1.010–1.015 when on Hill's® Prescription Diet® Canine s/d®</td>
<td>Encourage feeding only Hill's® Prescription Diet® Canine s/d®</td>
</tr>
<tr>
<td>Poor antimicrobial compliance</td>
<td>Urine culture positive with same bacteria identified prior to therapy</td>
<td>Assist owner in administering antibiotics</td>
</tr>
<tr>
<td><strong>Clinician-related</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect urolith type</td>
<td>Analyze retrieved urolith</td>
<td>Alter therapy for correct mineral type</td>
</tr>
<tr>
<td>Incorrect antibiotic</td>
<td>Positive urine culture with poor sensitivity for chosen antibiotic</td>
<td>Choose antibiotic based on sensitivity</td>
</tr>
<tr>
<td>Incorrect dose of antibiotic</td>
<td>Positive urine culture with same bacteria and susceptibility and decreased bacterial counts</td>
<td>Increase antibiotic dose or change antibiotics</td>
</tr>
<tr>
<td>Inadequate duration of antibiotic therapy</td>
<td>Positive urine culture with same bacteria in dog no longer on antibiotics</td>
<td>Continue antibiotics until 1 month past radiographic dissolution of stones</td>
</tr>
<tr>
<td><strong>Disease-related</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in bacterial sensitivity</td>
<td>Positive urine culture with changed susceptibility</td>
<td>Choose new antibiotic</td>
</tr>
<tr>
<td>Different infection</td>
<td>Positive urine culture with different bacteria</td>
<td>Choose new antibiotic effective against both bacteria</td>
</tr>
<tr>
<td>Compound urolith</td>
<td>Radiographic density variable within stone, identify via retrieved urolith</td>
<td>Adapt therapy for new mineral type</td>
</tr>
</tbody>
</table>

*Hill’s Pet Nutrition, Inc., Topeka, KS.

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**Risk Factors for the Development of Struvite Uroliths**

<table>
<thead>
<tr>
<th>Diet Type</th>
<th>Urine Characteristics</th>
<th>Genetic and Metabolic Factors</th>
<th>Concurrent Drugs</th>
</tr>
</thead>
<tbody>
<tr>
<td>High protein</td>
<td>Urose-positive urinary tract infection</td>
<td>Female</td>
<td>Glucocorticoids</td>
</tr>
<tr>
<td>Urine alkalizing</td>
<td>High urea concentration</td>
<td>Breed</td>
<td></td>
</tr>
<tr>
<td>High phosphorus</td>
<td>Hyperammonuria</td>
<td>Miniature schnauzer</td>
<td></td>
</tr>
<tr>
<td>High magnesium</td>
<td>High ionic phosphorus</td>
<td>Shih tzu</td>
<td></td>
</tr>
<tr>
<td>Low moisture</td>
<td>High magnesium</td>
<td>Bichon frise</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High pH</td>
<td>Miniature poodle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Retention of urine</td>
<td>Cocker spaniel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concentrated urine</td>
<td>Lhasa apso</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hyperadrenocorticism</td>
<td></td>
</tr>
</tbody>
</table>

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Diet Type

- High protein
- Urine alkalizing
- High phosphorus
- High magnesium
- Low moisture

Urine Characteristics

- Urose-positive urinary tract infection
- High urea concentration
- Hyperammonuria
- High ionic phosphorus
- High magnesium
- High pH
- Retention of urine
- Concentrated urine

Genetic and Metabolic Factors

- Female
- Breed
- Miniature schnauzer
- Shih tzu
- Bichon frise
- Miniature poodle
- Cocker spaniel
- Lhasa apso
- Hyperadrenocorticism

Concurrent Drugs

- Glucocorticoids
Struvite uroliths usually occur because of urinary tract infections (UTIs) with urease-producing bacteria such as *Staphylococcus* spp. or *Proteus* spp. Occasionally, struvite uroliths occur without a UTI (so-called sterile struvite uroliths). The diagnosis of struvite uroliths is not an endpoint of a diagnostic work-up; it is important to investigate mechanisms for development of a UTI, particularly if infections are recurrent or persistent. Use of a struvite dissolution diet is recommended when attempting medical treatment because it will hasten the dissolution process. During medical dissolution, a lateral abdominal radiograph should be taken and a urinalysis conducted to ensure compliance by owner and patient as well as to monitor the dissolution process.

During dissolution, antimicrobial therapy should be continued until uroliths are completely dissolved. Prevention of infection-induced struvite uroliths is dependent on prevention or early treatment of urinary infections. Administering an acidifying agent or feeding a diet with added acidifying capability facilitates prevention of sterile struvite uroliths. Recurrence of UTI or infection-induced struvite uroliths warrants further diagnostic testing to determine the reason(s) for recurrent UTIs. Causes include systemic impairment of host defense mechanisms (e.g., hyperadrenocorticism or glucocorticoid therapy, diabetes mellitus, hypothyroidism, polyuric states [renal failure]) or impairment of local host defense mechanisms (e.g., urinary bladder cancer).

Struvite is common in young dogs, while calcium oxalate is more common in older dogs. Struvite uroliths usually occur because of urinary tract infections (UTIs) with urease-producing bacteria such as *Staphylococcus* spp. or *Proteus* spp. Although the role of diet in dissolution of struvite urolithiasis in dogs has been established, the role of dietary modification in the prevention of struvite uroliths is less well defined. Theoretically, limiting the intake of protein, phosphorus, and magnesium and producing acidic urine may be of benefit in preventing struvite uroliths; however, a UTI with a urease-producing microbe is the most common cause of struvite uroliths in dogs. Therefore, if such an infection occurs while a dog is eating a struvite prevention diet, it is still likely that struvite uroliths will form.

Whether modification of dietary components is effective in preventing a UTI is also unknown. Acidification of urine is sometimes recommended for humans with recurrent UTIs. Indeed, most bacteria cannot live in urine with a pH below approximately 5.5; however, dogs are not readily able to acidify their urine to a level below this pH. Consumption of maintenance adult diets and the struvite dissolution or prevention diet by clinically healthy dogs results in production of urine with a pH of approximately 5.8 to 6.4. This pH range is not likely to prevent a bacterial UTI. In addition, consumption of a diet that promotes diuresis may predispose dogs to development of bacterial UTI because most bacteria cannot survive in highly concentrated urine.

In dogs with sterile struvite uroliths, dietary modification is important. In three related dogs with sterile struvite uroliths, administration of an acidifying agent or consumption of a struvite prevention diet formulated to contain an acidifying agent was successful in preventing recurrence of uroliths. These dogs produced alkaline urine when they were consuming adult maintenance diets. Medical management of struvite uroliths in dogs offers an alternative to surgical management. However, owner and patient compliance is essential for successful medical dissolution and prevention. Struvite uroliths may recur if risk factors are not appropriately addressed (see Struvite Urocystoliths in Adult Dogs).

REFERENCES


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**ARTICLE #1 CE TEST**

The article you have read qualifies for 1.5 contact hours of Continuing Education Credit from the Auburn University College of Veterinary Medicine. Choose the best answer to each of the following questions; then mark your answers on the postage-paid envelope inserted in *Compendium.*

1. The most common location of struvite uroliths within the urinary tract of dogs is the
   a. bladder.
   b. urethra.
   c. kidney.
   d. ureter.

2. Clear risk factors for infection-induced struvite urolith formation include all of the following except
   a. staphylococcal UTI.
   b. urine retention.
   c. *E. coli* UTI.
   d. hyperadrenocorticism.

3. Treatment of struvite urocystoliths with the struvitolytic diet and antibiotics should
   a. decrease water intake.
   b. decrease urine pH.
   c. continue for 14 days.
   d. continue for 30 days.

4. The struvitolytic diet has a low ________ content.
   a. salt
   b. moisture
   c. protein
   d. fat

5. Urinalysis of animals with infection-induced struvite cystoliths usually does not identify
   a. hematuria.
   b. bacteruria.
   c. urine pH less than 6.5.
   d. pyuria.

6. Urease production has been associated with all these bacteria except
   a. enterococcus.
   b. Klebsiella.
   c. Proteus.
   d. Staphylococcus.

7. When treating infection-induced struvite uroliths, antibiotics should be continued until
   a. clinical signs resolve.
   b. stones are no longer visible on survey radiographs.
   c. urine culture is negative.
   d. 1 month after stones are no longer visible on survey radiographs.

8. Potential complications associated with consumption of the struvitolytic diet include all of the following except
   a. pancreatitis.
   b. exacerbation of hypertension.
   c. diabetes mellitus.
   d. decompensation of congestive heart failure.

9. Acetohydroxamic acid is a(n)
   a. antibiotic.
   b. urine alkalinizer.
   c. bacterial urease inhibitor.
   d. phosphorous supplement.

10. Sterile struvite uroliths in dogs are
    a. not recurrent.
    b. common.
    c. best treated with urinary acidification.
    d. associated with renal failure.