Feline uroliths and urethral plugs: Epidemiology, risk factors and pathogenesis

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Introduction

Urolithiasis is a common cause of morbidity in cats and affects both the upper and lower urinary tract. Mineral composition of feline uroliths is primarily struvite (magnesium ammonium phosphate hexahydrate) or calcium oxalate; together this represents approximately 90% of submitted feline uroliths globally (Figure 1). Less common are purine, cystine, xanthine, calcium phosphate, silica and mixed composition uroliths. Over the past 25 years mineral composition has changed in response to nutrition and the environment. Epidemiologic studies describe feline demographic and risk factors to help identify underlying mechanisms of urolith formation, which help enable optimal treatment and prevention strategies.

Prevalence

Few studies have evaluated the overall prevalence of uroliths in cats and there are no published studies of longitudinal trends. Previous estimates of the incidence of lower urinary tract disease (LUTD) in the United States and United Kingdom indicated uroliths affect 0.85 to 1.0% of cats per year.[1] Yet, the proportion of cats presenting for treatment to veterinary hospitals ranges from 1 to 6%.[1]

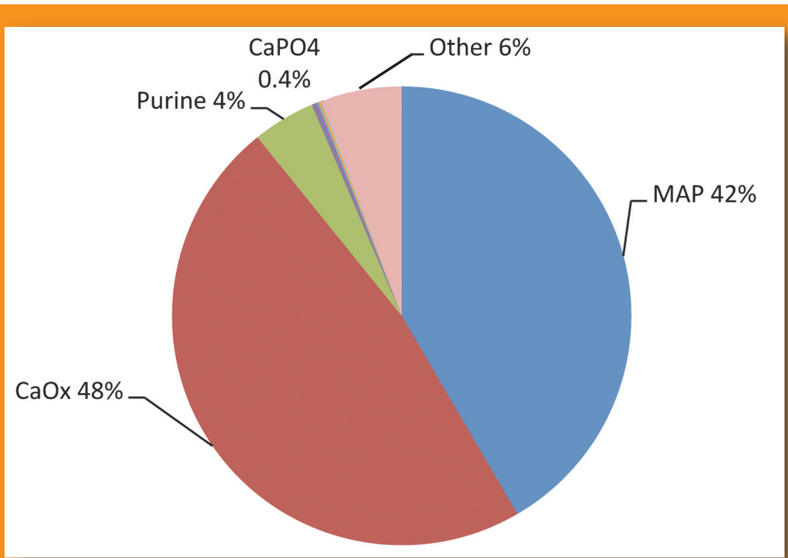

FIGURE 1 Average mineral composition of feline uroliths reported for 5 global regions. MAP = magnesium ammonium phosphate or struvite; CaPO4 = calcium phosphate, CaOx = calcium oxalate) (see Table 1 for additional details)

Table 1 Mineral composition of feline uroliths reported in the USA, Canada, and Europe

Site (year)	Minnesota[10] (2007)	California[7] (1984–2004)	Canada[11] (2008)	UK[12] (2002–2010)	Benelux[13] (2004)
Mineral composition	% of total feline urolith submission				
Struvite	48.6	37.8	42.1	47.7	32
Calcium oxalate	40.8	46.1	49.3	40.7/30.6	61
Purines	4.9	8.4	4.7	0.95	~3
Calcium phosphate	0.3	0.4	0.7	< 0.1	
Cystine	<0.1	0.1	<0.1	0.2	
Silica	<0.1	0.4	<0.1	< 0.1	
Xanthine	<0.1	0.1	0.1	0.2	
Other	5.1	6.7	2.98	< 10.3	4

Results of a cross-sectional study characterized the prevalence of urinary tract disease in 15,226 cats seen at private veterinary practices in the United States.[2] The combined prevalence of upper and lower urinary tract disease was 6.6%, and LUTD was diagnosed in 4.6% of all cats. Urolithiasis affected only 0.3% of this private practice population or 6.6% of cats with LUTD; this proportion is much lower than the prevalence reported in other studies. In a prospective clinical study conducted at the University of Minnesota, 143 untreated cats with hematuria, dysuria, urethral obstruction, or a combination of these signs were evaluated; 32 (22.4%) had urethral plugs, 30 (21%) had urolithiasis, and two (1.4%) had UTI.[3] In other studies the proportion of cats with LUTD related to uroliths varied from 11.8–22%.[4–6] Uroliths primarily are found in the lower urinary tract (93%), but may occur in all areas of the urinary tract. Cannon[7] reported the site prevalence of calcium oxalate uroliths as: 73% urinary bladder, 7.3% ureters, 4.3% kidneys, 13% urethra and 2% voided. Upper urinary tract uroliths, though less common than urocystoliths, have emerged as an important association with acute and chronic kidney disease over the past two decades.[8] While struvite is most commonly associated with urethral plugs, feline ureteroliths are reported to contain calcium oxalate 98% of the time.[9]

Urolith composition has changed dramatically over the past three decades. Sequential data from the Minnesota Urolith Center and the GV Ling Urinary Stone Analysis Laboratory (University of California at Davis) indicate calcium oxalate uroliths represented less than 5% of feline urolith submissions before 1987 and over 50% of the submissions in 1999.[7,10] While there is some variation in the proportion of struvite and calcium oxalate uroliths among laboratories and between regions, calcium oxalate now represents one of the most common mineral components found in feline uroliths across the globe (Table 1).

The rapid increase in prevalence of feline calcium oxalate uroliths may be multifocal, but is temporally associated with the 1980s trend to modify feline diets to reduce the risk of uroliths, urethral plugs and urinary obstruction associated

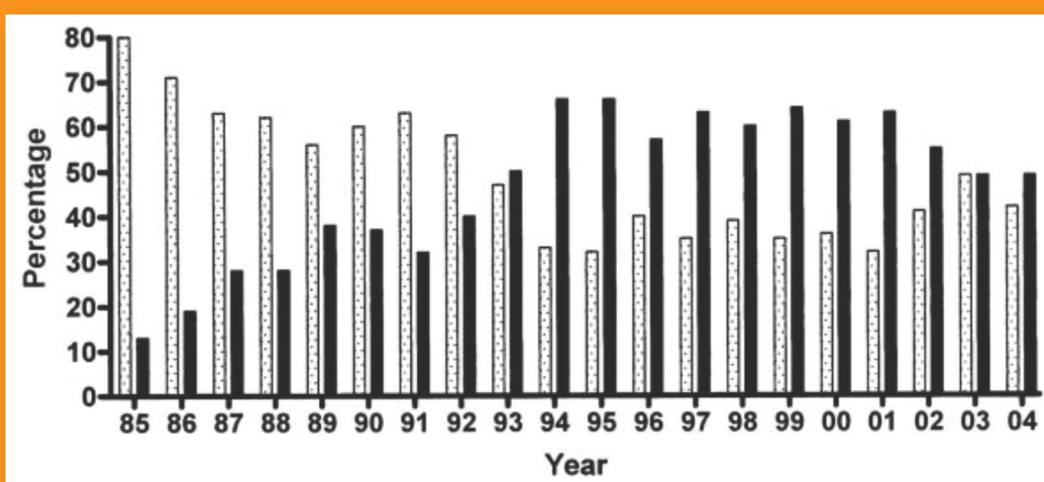

FIGURE 2 Percentage of feline calcium oxalate (black bars) and struvite (white bars) uroliths submitted to the GV.Ling Urinary Stone Analysis Laboratory at the University of California at Davis. (From Cannon AB et al. Evaluation of trends in urolith composition in cats: 5230 cases (1985–2004). *J Am Vet Med Assoc* 2007; 231: 570–576)

with struvite crystals. Dietary acidification and mineral restriction was broadly adopted and has been implicated as a risk factor in the proportional increase of calcium oxalate and decrease in struvite uroliths. Since 2002, the occurrence of calcium oxalate uroliths appears to have plateaued and even declined.[7,10] Calcium oxalate uroliths represent 40.8% of submissions and struvite uroliths rose to 48.6% of uroliths analyzed at the Minnesota Urolith Center, while the GV Ling Urinary Stone Analysis Laboratory (University of California at Davis) reported 44% struvite and 40% calcium oxalate between the period of 2002 and 2004 (Figure 2).[10] It is possible that moderation of dietary acidification may be the reason for the change.

The proportion of cats with lower urinary tract signs attributed to urethral obstruction varies from 18–58% and crystalline-matrix plugs account for approximately 21–60% of obstructions.[4,14] A 2002 report from the Minnesota Urolith Center noted that the prevalence of urethral obstruction had declined from 1.9–0.7% from 1980 to 1999 and that the percentage of obstructions related to plugs or urethroliths declined from 49–23% over that same period.[15] Urethral plugs are composed of at least 45–50% matrix and variable amounts of mineral; although 100% matrix plugs are commonly observed.[16] Despite the frequency of calcium oxalate uroliths, struvite has consistently remained the most common mineral identified in feline urethral plugs over the past 25 years. Of plugs submitted for quantitative analysis, the crystalline component has consistently been greater than 81% struvite (Table 2).[16–18]

Epidemiology and risk factors for disease

While epidemiologic studies suggest the etiology of feline urolithiasis and urethral plugs is multi-factorial, there is strong evidence that nutritional factors, genetics and environmental factors influence disease expression and mineral content of feline uroliths.

Non-dietary factors associated with the occurrence of uroliths include: age, breed, gender, reproductive status, body composition, housing, and potentially stress. Nutritional risk factors associated with uroliths include diet-induced urinary pH alterations, feeding method, food form, food variety, dietary supplements and water intake. Data supporting individual nutrients as sole risk factors are less robust and are specific to individual urolith types. Reported risk factors vary across studies and confound the interpretation of significance of the epidemiological evidence.

TABLE 2 Mineral composition of urethral plugs at the Minnesota Urolith Center (MUC) and the Canadian Veterinary Urolith Center (CVUC)

	MUC (1981–2007)	MUC (2007)	CVUC (1998–2003)
Mineral composition	% of urethral plugs submitted		
Struvite	83.5	91.5	81.1
Matrix	11.5	6.5	4.5
Calcium oxalate	0.9	1.0	6.6
Calcium phosphate	0.6	0.4	NR
Purines	0.1	0	NR
Other	3.4	0.6	NR

Calcium oxalate uroliths

Age Uroliths from all causes tend to occur in older cats; mean age across several studies is 7.0–7.6 years of age.[9,19–22] Cats ≥7 years but ≤10 years of age are reported to be 67 times more likely to develop calcium oxalate while struvite is more common in younger cats, both in Germany and the United Kingdom.[12,20–21]

Breed Results from early epidemiologic studies evaluating risk factors for calcium oxalate uroliths found domestic shorthair, domestic long hair, Persian and Himalayan breeds were at highest risk.[19–22] The Persian and Himalayan breeds were 5.5 to 8 times more likely to develop uroliths than non-Persian breeds.[19–21] In a study evaluating 1573 feline uroliths within Europe, European Shorthair 64.3% and purebred cats (Persian 15.2%, British shorthair 3.9%, Chartreaux 1.7%, Maine Coon 1.5%, Siamese 1.1%) were at highest risk.[20] A similar distribution of purebred cats (British Shorthair, Exotic Shorthair, Foreign Shorthair, Havana Brown, Himalayan, Persian, Ragdoll, and Scottish Fold cats) within the United States at risk of developing calcium oxalate uroliths has been reported.[21]

Gender Most studies report fairly similar gender distribution for most urolith types with a slight gender bias toward male cats. Regional variation in gender risk has been described and may explain contrasting reports.[19] Males are at 1.5 times the risk for calcium oxalate uroliths compared with females,[21–22] while female cats appear more at risk for struvite.[12–21] The biologic relevance of this difference has not been recognized except for male cats, who are at risk for urinary obstruction.

Neutering Neutering appears to be a significant risk factor across all uroliths types with 81.8% of cats presenting with urolithiasis having been surgically altered.[21]

Metabolic factors Kidney disease is commonly associated with calcium oxalate uroliths, particularly of the upper urinary tract.[7,10] The mechanism may be due to metabolic acidosis, which promotes hypercalciuria secondary to increased bone turn over and increased serum ionized calcium concentration, or altered calcium excretion at the level of the kidney.

Hypercalcemia is associated with an increased risk of calcium oxalate urolith formation; in cats with calcium oxalate uroliths, hypercalcemia was observed in 35% of the cases.[23] Conversely, in cats with idiopathic hypercalcemia, uroliths developed in 35% of the affected cats.[24] When severe, hypercalcemia results in increased urinary fractional excretion of calcium and hypercalciuria. Interestingly, epidemiological studies indicate a protective effect of increased dietary calcium.[21] Yet, feeding studies evaluating the effect of a therapeutic food on calcium oxalate risk in urolith-forming cats, support the benefit of controlled dietary calcium intake in reducing hypercalcemia.[25] Obesity results in a three-fold increase in risk for calcium oxalate urolithiasis.[21] The link of urolith formation to obesity has been suggested to be associated with a number of factors: decreased mobility and urine retention, inflammation and oxidative stress, or is a marker for increased mineral intake. Regardless, attention to body composition should be considered when managing risk-reduction in urolith prevention protocols.

Environment Assessment of environmental factors are limited. Both descriptive and epidemiological data supports increased risk for cats housed indoor-only (odds ratio 3.0) which has been associated with other comorbidities (ie, obesity and stress). Water source has not been defined as a risk factor although most cats are provided water from municipal sources, complicating adequate study design and power.

Nutritional factors

The impact of diet on the risk of feline calcium oxalate urolith occurrence has been evaluated in detail by Lekcharoensuk.[26] Cats with calcium oxalate uroliths were most commonly fed foods with lower levels of protein, calcium, phosphorus, potassium and moisture and highly acidified to induce acidic urinary pH (5.99–6.15). A decreased risk was observed in cats fed moderate calcium, and increased phosphorus and magnesium.

Water All studies support the benefit of increased moisture intake in reducing urolith risk. Increased water intake and urine dilution reduces the activity product of calcium oxalate and reduces risk for urolith formation by three-fold.[23,26] Strategies for increasing water intake include feeding high moisture foods, high protein diets, increased water availability or appeal, and stimulating thirst through the addition of dietary salt. All strategies increase water intake to variable degrees and appear safe in healthy cats. Contraindications exist for the use of salt and high-protein foods in cats with kidney disease, a viewpoint that may not be shared by all.

Urine pH Significant aciduria (urine pH <6.2) is a risk factor for calcium oxalate formation. Acidic urine alters several steps in the pathogenesis of urolithiasis from increasing mineral precursors to decreasing crystal inhibitors. All studies evaluating the role of diet on urinary acidification find a strong association with diet-related urinary acidification and calcium oxalate urolithiasis. In one study, cats fed acidifying diets or urinary acidifiers had a 5–20 times increased risk for developing calcium oxalate uroliths; the strongest association identified.[19] Other reports describe up to a three-fold increase in urolith risk with the lowest urine pH.[23,26]

Calcium It is important to recognize that the reported relationship of dietary calcium to urolith risk appears bimodal, suggesting a dual role for calcium in calcium oxalate formation. This dual risk for high and low levels of calcium intake has been reported in people. Low dietary calcium intake may increase the availability of intestinal oxalate uptake thereby increasing urinary oxalate excretion. Dietary calcium is known to complex with intestinal oxalate and promote fecal calcium oxalate excretion in the gut, thereby reducing urinary calcium and oxalate concentrations. At very high calcium intakes, increased calcium absorption may increase urinary excretion and calcium oxalate risk, although calcium uptake is well regulated in normal cats.[27]

Urolith inhibitors In addition to the effect of intraluminal calcium as an inhibitor of intestinal oxalate absorption, urinary inhibitors of calcium oxalate crystal formation include magnesium, pyrophosphate, potassium and citrate. The association of lower dietary phosphorus, potassium and magnesium with increased calcium oxalate risk has a logical association. The role of diet acidification and the impact on inhibitor urine concentration and function will be discussed elsewhere.

Oxalate There is little information about the nutritional risk of dietary oxalate. Oxalate is found in various vegetable products and is also a byproduct of endogenous ascorbate (vitamin C) metabolism. Over supplementation of vitamin C and fiber are known to increase oxalate intake in other species. Fiber is not significantly associated with oxalate uroliths[26] and modest vitamin C inclusion in feline diets does not increase urinary oxalate concentrations in healthy cats.[28] Investigation into the role of oxalate metabolizing gut microflora (*Oxalobacter formigenes*) is ongoing, but specific risk factors for uroliths are undefined.[29]

Protein Low protein diets (<8 g/100 kcal) were associated with an increased risk of calcium oxalate uroliths in epidemiologic studies.[26] High-protein meals have been reported to alter mineral excretion, increase water intake, increase urine volume, lower urinary oxalate and acidify urine in healthy cats.[30,31] While urine dilution and reduced oxalate could aid in urolith prevention, urine acidification may oppose such benefit. Feeding trials have resulted in minimal impact of high-protein foods on calcium oxalate activity product compared with moderate-protein diets when urine pH is controlled (Kirk, unpublished data).

Struvite Uroliths

Age Sterile struvite uroliths form typically in cats between 1 and 10 years of age and are more common in younger cats compared to cats with calcium oxalate uroliths (6.6 vs 7.6 years).[12,20] Risk for struvite urolith formation decreases after approximately 6 to 8 years of age in cats.[21]

Breed factors Chartreux, Domestic Shorthair, Foreign Shorthair, Himalayan, Oriental Shorthair, and Ragdoll cats have an increased risk of developing struvite uroliths. Himalayan and Persian cats had 2.6 times increased risk of developing struvite uroliths and seem to be prone to both struvite and calcium oxalate urolith formation.[21,23]

Gender Female cats are at higher risk for sterile struvite uroliths compared to males and in comparison to other urolith types.[12,21] While male cats are at risk for urethral plugs, of which struvite is the major crystalline component, they are 30% less likely to develop struvite uroliths.[21]

Neuter status Neutered cats represented 91% of cats presenting with struvite uroliths compared to 9% who are intact.

Environment Housing cats indoors is associated with two times the risk for struvite development compared to outdoor cats. Obesity and stress have been associated with increased risk of struvite uroliths, similar to calcium oxalate.[21]

Nutritional factors

Diets high in magnesium, phosphorus and protein, combined with alkaline urine pH have been associated with struvite risk for over 30 years. Other nutrients associated with increased risk include calcium, chloride, sodium and fiber.

Water Increasing moisture in the diet could help struvite urolith prevention and dissolution; however, this has not been critically evaluated. Oddly, epidemiological studies did not find a significant protective effect of foods high in moisture, which is likely explained by the primary role of urine pH and mineral control in sterile struvite prevention.[26] Foods high in fiber are recognized to increase risk of uroliths by approximately two-fold in epidemiologic studies as well as clinical observations. The increased struvite risk could be due to the hygroscopic nature of fibers in the gut and a subsequent reduction in urine volume.

Urine pH The relationship between urinary pH and struvite solubility is well established and the basis for the effective medical dissolution of struvite uroliths. Urine pH values from 6.5 to 6.9 are associated with two times the risk for sterile struvite urolith development compared with urine with a pH <6.[15]

Protein Consumption of high dietary protein in healthy cats increased water intake and urine volume, increased urine acidification and reduced struvite activity product.[30] However, in studies by Lekcharoensuk, no risk reduction was noted with increased protein.[26] The potential for increased phosphorus intake from protein consumption to negate benefits may explain the lack of benefit noted in other studies.

Magnesium Diets high in magnesium (0.36 to 1.40 mg of magnesium/kcal) were 3.7 times as likely to be associated with struvite uroliths compared with cats fed low magnesium (0.09 to 0.18 mg/kcal) foods.[26] Urinary magnesium excretion reflects dietary intake when body stores are replete. Increased magnesium intake has been shown to increase feline struvite formation.

Phosphorus Like magnesium, phosphorus is a major component of struvite and increased intake results in increased urinary phosphorus excretion and supersaturation with a key calculogenic substrate. Increased dietary phosphorus increases struvite risk by 3.5–4.4-fold at levels above 1.76 mg of phosphorus/kcal.[26]

Miscellaneous nutrients Other nutrients associated with struvite risk are increased intake of calcium (3 odds radio; OR), chloride (2 OR) and sodium (4 OR). Alterations in mineral metabolism or excretion and casual association with other stone-forming minerals (eg, sodium phosphate, calcium phosphate etc.) may explain these epidemiologic associations.[26]

Urate uroliths

Age Cats developing urate uroliths were at greatest risk between 4 and 7 years of age (mean age 6.2 years) with over 50 times greater risk of developing urate uroliths than cats less than 1 year of age.[32]

Breed factors Cats developing urate uroliths were most often purebreds with Bengal, Berman, Egyptian Mau, European Shorthair, Havana Brown, Ocicat, Oriental, Ragdoll, Rex Snowshoe and Sphinx at increased risk. American Shorthair, Himalayan, Manx and Persian breeds were protected.[32]

Gender Most studies report fairly similar gender distribution for urolith types with a slight gender bias toward male cats. Males have 1.1 times the risk as females for urate uroliths.[32]

Neutering Neutering or castration appears to be a significant risk factor for uroliths with 81.8% being surgically altered. Compared with surgically unaltered cats, the risk of developing urate uroliths was 12 times greater in neutered cats.[32]

Metabolic Urate stones in cats are often associated with portocaval anomalies.

Nutritional factors Specific nutritional factors have not been associated with urate risk in cats although decreased dietary protein and urinary alkalization are suggested for prevention.

Urethral plugs

Age In a study of 77 European cats with lower urinary tract disease, urethral plugs occurred in 10% of the cases.[6] Ages ranged from 2–11 years with a mean age of 4 years. In the US, the greatest risk was in those cats 4–6 years of age with an odds ratio of 2.9.[33]

Breed Domestic Shorthair, Norwegian Forest, Persian and Siamese are reported to have increased risk of urethral plugs.[6,14]

Gender As expected, all cats with urethral plugs were male, with 92% being neutered and 8% intact.[8]

Metabolic Primary metabolic abnormalities associated with urethral obstruction are uncommon, aside from those secondary to acute urethral obstruction. Obesity has been reported as a possible risk factor, and a larger proportion of cats reported by Gerber were overweight (mean 5.7 kg; range 4.5–7.2 kg) compared to cats with urinary tract infections.

Housing Indoor housing appears to be a common risk factor for urethral plugs. Of eight cats described with plugs, 75% were housed exclusively indoors.[6] This finding is consistent with the risk of idiopathic LUTD, in general.

Nutrition Nutritional factors are similar to those for cats with struvite disease, and cats with urethral plugs are more commonly fed a major proportion of their diet as dry foods or dry food exclusively.[6]

Pathogenesis – urolith formation

Overview Urolith formation, dissolution, and prevention involves complex physical processes. Major factors include:

- Supersaturation resulting in crystal formation.
- Effects of inhibitors of crystallization and inhibitors of crystal aggregation and growth.
- Crystalloid complexors.
- Effects of promoters of crystal aggregation and growth.
- Effects of non-crystalline matrix.[34,35]

Concept of urine saturation Urolith formation is associated with two complementary but separate phases: initiation and growth. It appears that initiating events are not the same for all types of uroliths. In addition, factors that initiate urolith formation may be different from those that allow it to grow. The initial step in formation of a urolith is formation of a crystal nidus (or crystal embryo). This phase of initiation of a urolith formation, called nucleation, is dependent on supersaturation of urine with calculogenic crystalloids. The degree of urine supersaturation may be influenced by the magnitude of renal excretion of the crystalloid, urine pH, and/or crystallization inhibitors or promoters in urine. Non-crystalline proteinaceous matrix substances may also play a role in nucleation in some instances.

Nucleation has been classified as homogeneous or heterogeneous. Homogeneous nucleation occurs spontaneously in highly supersaturated urine in the absence of foreign substances; therefore, the nidus is composed of identical crystalloids. Heterogeneous nucleation is catalyzed by foreign material such as suture material, indwelling catheters, tissue debris, crystal embryos of different composition, and so on (Figure 3). Urine contains many impurities that might promote heterogeneous nucleation and initiate crystal formation at a concentration of crystalloids below the formation concentration. These substances may be thought of as facilitators or potential facilitators of crystallization. Any crystal type may be a potential nidus for nucleation of another crystal type. A greater degree of supersaturation (that is, a higher formation product) is required for homogeneous nucleation than for heterogeneous nucleation (Figure 4). Once nucleation has occurred, however, crystal growth can occur at any degree of supersaturation (even at metastability).

Further growth of the crystal nidus is dependent on:

- Its ability to remain in the lumen of the urinary system.
- The degree and duration of supersaturation of urine with crystalloids identical to or different from that in the nidus.
- Physical characteristics of the crystal nidus. If they are compatible with other crystalloid, crystals may align themselves and grow on the surface of others. This is called epitaxial growth and may represent a heterogeneous form of nucleation, and may account for mixed and compound uroliths.

An important driving force behind urolith formation is saturation state of urine with lithogenic substances (Figure 4). When a solution such as urine is saturated, it refers to the maximal amount of a substance, such as calcium oxalate, that can be completely dissolved. This point is termed the thermodynamic solubility product. When calcium oxalate is present in urine at a concentration less than the solubility point, the urine is undersaturated with calcium oxalate and it completely dissociates and dissolves. When calcium oxalate is present in urine at a concentration that is equal to the solubility point, the urine is saturated with calcium oxalate and calcium oxalate may begin to precipitate. When calcium oxalate is present in urine at a concentration above the solubility point, the urine is supersaturated with calcium oxalate and calcium oxalate precipitates.

Urine contains ions and proteins that interact and/or complex with calcium and oxalic acid so as to allow them to remain in solution. This explains why calcium and oxalic acid in urine do not normally precipitate to form calcium oxalate

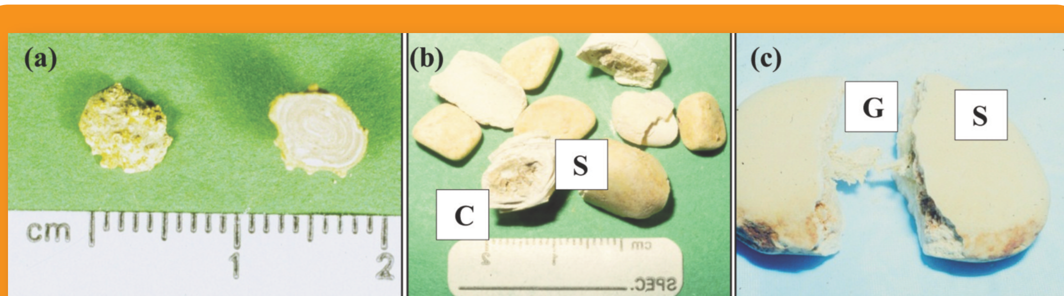

FIGURE 3 Example of (a) homogeneous nucleation and (b and c) heterogeneous nucleation. (a) Ammonium urate urolith removed from a 3-year-old, intact male, English Bulldog. Note the laminations. (b) Compound urolith removed from a 4-year-old, spayed female Toy Poodle. The outer layers are composed of infection-induced struvite (S) around a calcium oxalate nidus (c). (C) Infection-induced struvite urolith removed from a 2-year-old, spayed female Miniature Schnauzer. The urolith (S) formed around a piece of fibrous material (gauze sponge, G), inadvertently left behind at a previous cystotomy for urolith removal

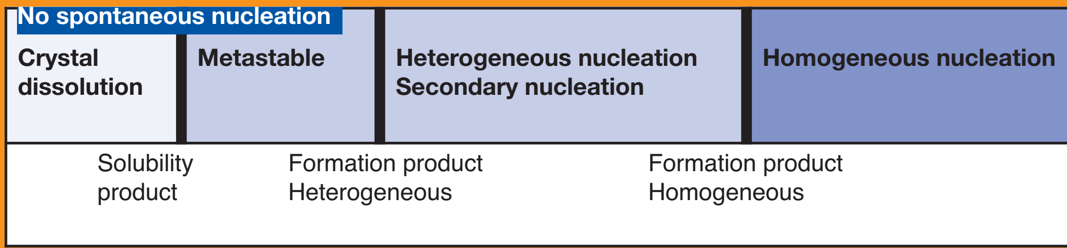

FIGURE 4 States of urinary saturation

crystals. Urine is normally supersaturated with respect to calcium and oxalic acid. But energy is required to maintain this state of calcium and oxalic acid solubility, and, therefore, the urine must constantly 'struggle' to maintain calcium and oxalic acid in solution. Thus, urine is described as being metastable. The metastable region refers to the degree of supersaturation of a crystalloid that lies between the solubility product and the formation product. Metastability applies to those solutions (such as urine) that have the capacity to retain more of a compound in solution than would be predicted by knowledge of its true solubility in water. A metastable solution is thermodynamically unstable, but does not contain enough energy to initiate crystal formation. However, if crystals are already present, they may grow.

If the concentration of calcium and oxalic acid is increased, a threshold is eventually reached at which urine cannot hold more calcium and oxalic acid in solution. The urine concentration at which this occurs is the formation point of calcium oxalate. Above the thermodynamic formation product, urine is oversaturated and unstable with respect to calcium and oxalic acid. Thus, calcium oxalate crystals will precipitate, grow in size, and aggregate together.

Urine is a complex solution containing a variety of substances that can inhibit or promote crystal formation and growth.[36–44] Inhibitors include molecules that reduce calcium oxalate and calcium phosphate supersaturation. Some inhibitors (eg, citrate, magnesium, pyrophosphate) form soluble salts with calcium, oxalic acid or phosphate, and thereby reduce the quantity of calcium, oxalate or phosphate available for precipitation. Other inhibitors (eg, nephrocalcin, uropontin, glycosaminoglycans, Tamm-Horsfall glycoprotein, other inert ions) interfere with the ability of calcium and oxalic acid to combine, and thereby minimize crystal formation and growth. Also, glycosaminoglycans act as protectors by preventing adherence of crystals to the urinary tract mucosa.

Summary

Uroliths are a common cause of feline morbidity. Prevalence patterns are globally similar with struvite and calcium oxalate representing over 90% of all urolith types, and changes in prevalence mirrored in many regions. Despite variability across studies and urolith composition, several key risk factors appear common. Shorthair, Himalayan and Persian breeds are consistently reported within high risk for urolithiasis, although purebred cats as a whole seem more proportionally affected. Most cats developing urolithiasis are middle aged with a mean age of 7, although cats with struvite and urate are somewhat younger. Being neutered and housed indoors are risk factors for major urolith types with gender distribution varying by urolith composition and region. Urethral plugs are consistently found in male cats. Nutritional risk factors common to all uroliths are low water intake and the diet-regulated urinary pH. Dietary protein, fat and mineral content may influence urolith risk, but the relative risks reported in epidemiologic studies are less robust. Use of epidemiological findings coupled with a strong understanding of the pathophysiological process will help direct future research and evidence-based treatment and prevention.

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