

# Distribution of urinary calculi and its association with clinical and laboratory findings in dogs and cats with stone analysis at Chulalongkorn Animal Teaching Hospital, Thailand (2020-2024)

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## *Abstract*

Urinary calculi are commonly encountered in veterinary practice; however, information regarding their distribution of stone that underwent analysis and associated clinical findings remains limited. This study investigated the distribution of urolithiasis and the associations between stone types and clinical and laboratory findings in dogs and cats presented to the Chulalongkorn Small Animal Teaching Hospital between 2020 and 2024. The three most common stone types in both species were calcium oxalate (CaOx), struvite, and urate, with relatively stable trends over the 5-year period. Small-breed dogs had a higher risk of developing CaOx urolithiasis than medium-breed dogs (OR = 10.4, 95% CI = 4.64–22.45,  $P < 0.001$ ), whereas medium-breed dogs were at greater risk for urate (OR = 8.0, 95% CI = 2.98–22.93,  $P < 0.001$ ) and cystine urolithiasis (OR = 92.9, 95% CI = 13.59–1021,  $P < 0.001$ ). Uroliths were most commonly found in the urinary bladder of older intact male dogs and neutered male cats. Calcium oxalate uroliths were associated with the highest age at presentation and the longest recurrence period. Female dogs were 12.5 times more likely to develop struvite than CaOx urolithiasis. Compared with dogs with CaOx urolithiasis, dogs with struvite urolithiasis more frequently exhibited anorexia, urinary incontinence, hematuria, higher urine pH, bacteriuria, pyuria, and increased white blood cell counts, suggesting urinary tract infection. Urinary crystals were infrequently detected despite confirmed urolithiasis and were not specific to stone type. These findings provide useful information for the diagnosis and management of canine and feline urolithiasis.

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**Keywords:** cats, clinical signs, dogs, laboratory results, urolithiasis

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## Introduction

Urinary calculi are among the most common conditions encountered in small animal practice. In general, uroliths are polycrystalline concretions composed of organic and inorganic crystalloids with a small amount of organic matrix. Uroliths can be classified according to their mineral composition, including struvite (magnesium ammonium phosphate; MAP), calcium oxalate (CaOx), urate, cystine, silica, compound, and mixed stones. Historical data demonstrate notable shifts in urolith prevalence over time. The incidence of urolith types shifted, with struvite tending to be lower while CaOx tended to be higher in both dogs and cats from 1981 to 2007 (Osborne *et al.*, 2009). In Thailand, studies conducted between 2009 and 2015 reported that struvite was the predominant urolith type in dogs (44%), followed by CaOx (27%) (Hunprasit *et al.*, 2017). In contrast, cats most commonly developed CaOx uroliths (49.5%), while struvite accounted for 38% of cases (Hunprasit *et al.*, 2019a).

Several demographic, etiologic, and environmental factors are involved in urolith formation (Gomes *et al.*, 2018). Demographic factors include species, breed, age, sex, and genetic predisposition, which may contribute to imbalances in electrolyte homeostasis as well as abnormalities in hormonal and nutrient metabolism (Bartges and Corbee, 2023). Certain urolith types are associated with specific breeds; for example, urate urolithiasis is commonly reported in Dalmatians (Burggraaf *et al.*, 2021). Cystine urolithiasis is frequently observed in mature intact male dogs, particularly during young adulthood to middle age (Brons *et al.*, 2013; Kovaříková *et al.*, 2021). Etiologic factors include toxic agents and urinary tract infections. Hydroxyproline metabolism can increase oxalate excretion and promote CaOx formation, whereas urinary tract infection is strongly associated with struvite urolithiasis (Bartges and Corbee, 2023). Environmental factors such as water intake, diet, and living conditions also contribute to urolith formation. High dietary protein intake, urine supersaturation, low water consumption, and alkaline urine are associated with the development of certain types of uroliths (Gomes *et al.*, 2018).

The most common clinical findings in animals with urolithiasis are associated with abnormalities in voiding behavior, including pollakiuria, hematuria, and stranguria. Systemic signs such as anorexia, lethargy, and vomiting may also occur secondary to urinary tract infection and uremia, particularly in cases of upper urinary tract obstruction (Monnet and Kyles, 2023).

The diagnosis of urolithiasis at initial presentation is based on a combination of history taking, clinical findings, laboratory testing, and diagnostic imaging. However, the mineral composition of uroliths can only be definitively identified through stone analysis. Information regarding the distribution, demographic characteristics, and associations between stone types and clinical and laboratory findings in dogs and cats in Thailand over the past five years remains limited. Therefore, the objectives of this study were to

determine the distribution and types of urinary calculi in dogs and cats presented to the Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University, between 2020 and 2024, and to evaluate factors associated with different types of urolithiasis, including age, breed, sex, urolith location, recurrence interval, clinical presentation, and laboratory findings.

## Materials and Methods

**Location and population:** This study was conducted at the Faculty of Veterinary Science, Chulalongkorn University, Bangkok, Thailand, between 1 January 2020 and 31 December 2024. Ethical approval was not required according to the guidelines of the Animal Care and Use Committee, Faculty of Veterinary Science, Chulalongkorn University. The study population included all dogs and cats with a confirmed diagnosis of urolithiasis based on radiographic and/or ultrasonographic findings that underwent surgical removal or non-surgical retrieval of uroliths, with urolith specimens submitted for compositional analysis and corresponding clinical data available for review. One dog diagnosed with leukemia was excluded from the study because of severe leukocytosis.

**Data retrieval:** Retrospective data were retrieved from the Hospital Information System (HIS) of the Small Animal Teaching Hospital, Faculty of Veterinary Science, Chulalongkorn University. The collected data included age, age at first episode, breed, sex, neuter status, recurrence interval from the previous episode, anatomical location of uroliths, clinical signs, and laboratory findings. Complete blood count (CBC) parameters included red blood cell (RBC) count, white blood cell (WBC) count, platelet (Plt) count, hemoglobin (Hb), and hematocrit (Hct). Biochemical profiles included blood urea nitrogen (BUN), plasma creatinine concentration (Cr), total protein (TP), albumin (Alb), inorganic phosphate (Pi), total calcium (Ca), alanine transaminase (ALT), and alkaline phosphatase (ALP). Urinalysis results included urine specific gravity, urine pH, and urine sediment findings, including the presence of crystals, WBCs, bacteria, and RBCs. All laboratory data were obtained within 14 days prior to surgical removal of the uroliths.

Urolith composition data were obtained from the Minnesota Urolith Center, University of Minnesota, USA, where specimens were quantitatively analyzed using polarized light microscopy and infrared spectroscopy (Ulrich *et al.*, 1996). Uroliths were classified as a specific mineral type when a single layer contained  $\geq 70\%$  of one predominant mineral. Mixed uroliths were defined as single-layer stones in which no mineral component exceeded 70%. Compound uroliths were identified as multilayered stones in which each layer contained  $\geq 70\%$  of a single mineral, with differing mineral compositions among layers (Hunprasit *et al.*, 2019a).

**Statistical analysis:** All statistical analyses were performed using GraphPad Prism (Version 9.4.1; GraphPad Software Inc., San Diego, CA, USA). In dogs, CaOx, struvite, urate, cystine, and calcium phosphate carbonate (CaP carbonate) uroliths were analyzed, whereas in cats, CaOx, struvite, and urate uroliths were included in the analysis. Other urolith types were excluded because of small sample sizes. Continuous variables, including age, age at first occurrence, recurrence interval, hematologic and biochemical parameters, urine specific gravity, and urine pH, were presented as mean  $\pm$  SE. Data distribution was assessed for normality using the Shapiro–Wilk test. One-way ANOVA or one-way ANOVA on ranks was used to compare differences among urolith types, followed by Dunnett's or Dunn's post-hoc tests for pairwise comparisons, respectively. Calcium oxalate urolithiasis was used as the reference group because it had the highest number of submissions.

The distribution of urolith types, breed, and urolith locations were reported as percentages. Dog breeds were categorized into two size groups: small breeds (Pomeranian, Chihuahua, Shih Tzu, Yorkshire Terrier, Poodle, Pug, Maltese, and Schnauzer) and medium breeds (Bulldog, Welsh Corgi, Pit Bull, and Beagle). The risk of developing each urolith type between small- and medium-breed dogs was evaluated using

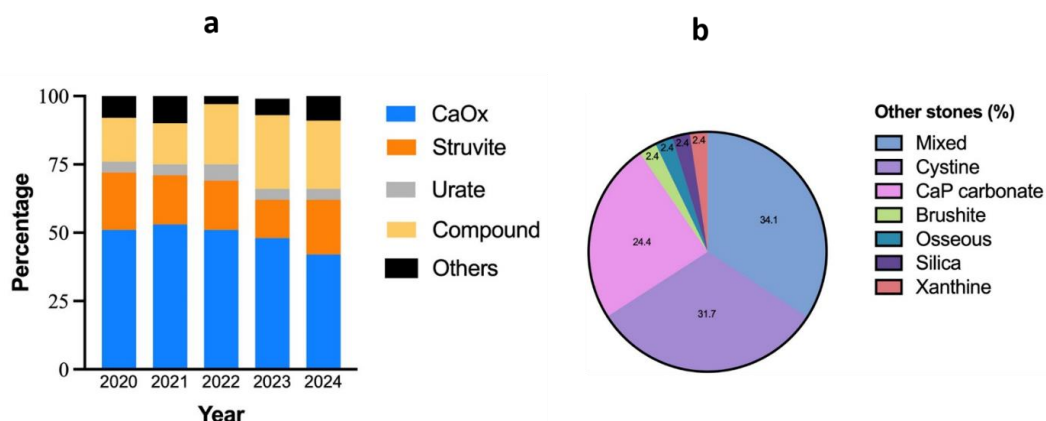
odds ratios (ORs) with 95% confidence intervals (CIs). The univariate Chi-square or Fisher's exact tests were used to compare sex, neuter status, clinical signs, and urine sediment findings between each urolith type and CaOx urolithiasis. Odds ratios were calculated for significant variables. A  $P$ -value  $< 0.05$  was considered statistically significant.

## Results

### Canine uroliths:

**Incidence of uroliths in dogs:** Between 2020 and 2024, a total of 544 canine urolith submissions were collected. The number and percentage of dogs with CaOx, struvite, urate, compound, and other uroliths were 264 (48.5%), 99 (18.2%), 25 (4.6%), 116 (21.3%), and 40 (7.4%), respectively (Fig. 1a). Other urolith types included mixed, cystine, CaP, brushite, osseous, silica, and xanthine uroliths (Fig. 1b).

Over the 5-year study period, CaOx consistently remained the most frequently identified urolith type each year. Struvite uroliths showed slight year-to-year fluctuations without a clear increasing or decreasing trend. In contrast, compound uroliths demonstrated an overall increasing trend, particularly during the later years of the study period.



**Figure 1** Annual number of canine urolithiasis cases classified by urolith type (a) and percentage distribution of other urolith types (b) during 2020–2024.

**Demographic characteristics in dogs:** The most commonly affected breeds were Pomeranian, Chihuahua, Shih Tzu, and Yorkshire Terrier, accounting for 22.2%, 16.3%, 14.1%, and 5.3% of cases, respectively. CaOx and struvite uroliths were predominantly identified in small-breed dogs, representing 77.6% and 53.5% of cases, respectively, whereas urate and cystine uroliths were found in both small- and medium-breed dogs (Table 1). Small-breed dogs had a significantly higher risk of developing CaOx urolithiasis compared with medium-breed dogs (OR = 10.4, 95% CI = 4.64–22.45,  $P < 0.001$ ). In contrast, medium-breed dogs, particularly Bulldogs and Welsh Corgis, had a significantly increased risk of urate and cystine urolithiasis (OR = 8.0, 95% CI = 2.98–22.93,  $P < 0.001$ ; and OR = 92.9, 95% CI = 13.59–1021,  $P < 0.001$ , respectively) compared with small-breed dogs.

Urolithiasis was predominantly observed in older dogs (Table 1). Dogs with struvite, urate, and cystine uroliths were significantly younger than dogs with CaOx uroliths. Dogs with CaOx urolithiasis also had a significantly higher mean age at the first episode compared with dogs with struvite ( $P < 0.001$ ), urate ( $P < 0.001$ ), and cystine urolithiasis ( $P < 0.001$ ). The youngest age at presentation was observed in dogs with cystine urolithiasis. The recurrence interval for CaOx urolithiasis was significantly longer than that for urate urolithiasis ( $P < 0.01$ ).

Most uroliths were retrieved from the lower urinary tract regardless of mineral composition (Table 1). Nephrolithiasis was identified in only 8 of 544 dogs, including 3 compound, 2 urate, 1 CaOx, 1 struvite, and 1 CaP carbonate uroliths. Ureterolithiasis was identified in 21 dogs, including 8 CaOx, 6 compound, 4 struvite, 2 CaP carbonate, and 1 osseous uroliths.

**Neuter status and sex in dogs:** Sex distribution demonstrated a predominance of intact males across all urolith types except struvite urolithiasis. When comparisons were made among urolith types, sex, but not neuter status, differed significantly. Female dogs were 12.5 times more likely to present with struvite urolithiasis than CaOx urolithiasis (Table 2).

**Clinical signs in dogs:** Clinical signs were recorded in 544 dogs, with anorexia and lethargy observed in 25.9% and 21.3% of cases, respectively. Dogs with struvite and urate urolithiasis were 2.63 and 4.0 times

more likely to exhibit anorexia, respectively, compared with dogs with CaOx urolithiasis ( $P < 0.05$ ) (Table 3).

Voiding disorders observed in dogs with urolithiasis included oliguria, pollakiuria, stranguria, urinary incontinence, and hematuria, occurring in 19.7%, 18.0%, 8.8%, 6.1%, and 4.0% of cases, respectively. Compared with dogs with CaOx urolithiasis, dogs with struvite urolithiasis were less likely to exhibit oliguria ( $P < 0.001$ ) but were 2.1 times more likely to present with urinary incontinence ( $P < 0.05$ ) and 2.98 times more likely to exhibit hematuria ( $P < 0.001$ ) (Table 3).

**Table 1** Demographic characteristics of dogs with urolithiasis according to urolith type.

| Dogs                                                              | CaOx               |      | Struvite          |      | Urate             |      | Cystine     |      | CaP Carb    |      |
|-------------------------------------------------------------------|--------------------|------|-------------------|------|-------------------|------|-------------|------|-------------|------|
| Number of cases                                                   | 264                |      | 99                |      | 25                |      | 13          |      | 10          |      |
| Breed                                                             | Pomeranian         | 28.0 | Shih Tzu          | 19.2 | Bulldog#          | 24.0 | Bulldog#    | 53.8 | Pomeranian  | 40.0 |
|                                                                   | Chihuahua          | 22.7 | Pomeranian        | 12.1 | Chihuahua         | 16.0 | Welsh Corgi | 15.4 | Poodle      | 10.0 |
|                                                                   | Shih Tzu           | 11.0 | Chihuahua         | 8.1  | Pomeranian        | 8.0  | Chihuahua   | 7.7  | Jack Russel | 10.0 |
|                                                                   | Yorkshire Terrier  | 6.8  | Poodle            | 5.1  | Shih Tzu          | 8.0  | Mixed       | 23.1 | Mixed       | 40.0 |
|                                                                   | Poodle             | 3.8  | Bulldog#          | 5.1  | Yorkshire Terrier | 8.0  |             |      |             |      |
|                                                                   | Pug                | 2.7  | Yorkshire Terrier | 4.0  | Dalmatian         | 4.0  |             |      |             |      |
|                                                                   | Miniature Pinscher | 1.5  | Pug               | 3.0  | Mixed             | 12.0 |             |      |             |      |
|                                                                   | Maltese            | 1.5  | Schnauzer         | 2.0  | Other             | 20.0 |             |      |             |      |
|                                                                   | Schnauzer          | 1.1  | Welsh Corgi       | 2.0  |                   |      |             |      |             |      |
|                                                                   | Mixed              | 16.7 | Pit bull          | 2.0  |                   |      |             |      |             |      |
|                                                                   | Other              | 4.2  | Mixed             | 32.3 |                   |      |             |      |             |      |
|                                                                   |                    |      | Other             | 5.1  |                   |      |             |      |             |      |
| Age (years)<br>(262/97/25/13/9)                                   | 9.3±0.2            |      | 7.6±0.3 ***       |      | 5.7±0.6 ***       |      | 4.5±0.6 *** |      | 8.9±1.4     |      |
| Age at the 1 <sup>st</sup> episode<br>(years)<br>(235/87/22/11/6) | 9.2±0.2            |      | 7.6±0.4 ***       |      | 5.9±0.7 ***       |      | 4.4±0.8 *** |      | 9.8±2.2     |      |
| Recurrence (months)<br>(29/11/3/2/2)                              | 38.5±4.5           |      | 19.9±3.7          |      | 0.9±0.1**         |      | 20.5±13.5   |      | 16.0±8.0    |      |
| Location (%)<br>(254/91/22/12/9)                                  |                    |      |                   |      |                   |      |             |      |             |      |
| Upper                                                             | 3.5                |      | 4.4               |      | 9.1               |      | 0           |      | 22.2        |      |
| Lower                                                             | 95.7               |      | 93.4              |      | 90.9              |      | 100         |      | 77.8        |      |
| Both                                                              | 0.8                |      | 2.2               |      | 0                 |      | 0           |      | 0           |      |

Age, age at the first episode, and recurrence interval are presented as mean ± SE. Breed distribution and anatomical location are presented as percentages. #Bulldog breeds include French Bulldog, Old English Bulldog, English Bulldog, Australian Bulldog, and American Bulldog. Differences among urolith types were analyzed using one-way ANOVA, with CaOx uroliths used as the reference group. \*\* $P < 0.01$ , \*\*\* $P < 0.001$ . Numbers in parentheses indicate the number of dogs included for each urolith type, in the order listed.

**Table 2** Associations of sex and neuter status with urolith types in dogs.

|                         | Intact    | Neutered | P-value       | Male | Female         | P-value |
|-------------------------|-----------|----------|---------------|------|----------------|---------|
| CaOx                    | 156       | 95       | 0.166         | 232  | 32             | < 0.001 |
| Struvite                | 69        | 27       |               | 36   | 62             |         |
| Urate                   | 16        | 8        |               | 19   | 6              |         |
| Cystine                 | 10        | 1        |               | 13   | 0              |         |
| CaP carbonate           | 6         | 2        |               | 8    | 2              |         |
| <b>Female vs Male</b>   | <b>OR</b> |          | <b>95% CI</b> |      | <b>P-value</b> |         |
| (Struvite vs CaOx)      | 12.5      |          | 7.08-21.50    |      | < 0.001        |         |
| (Urate vs CaOx)         | 2.3       |          | 0.86-6.15     |      | 0.116          |         |
| (CaP carbonate vs CaOx) | 1.8       |          | 0.37-8.00     |      | 0.354          |         |

CaOx urolith was used as the reference category for odds ratio calculations. OR > 1 indicates increased odds relative to CaOx. Associations were evaluated using Chi-square. CI, confidence interval; OR, odds ratio.

**Hematology and serum biochemistry in dogs:** For CBC results, RBC, Hb, Hct, and Plt counts were within normal ranges across all urolith types and did not differ significantly from dogs with CaOx urolithiasis. However, WBC counts were significantly higher in dogs with struvite urolithiasis ( $n = 93$ ) than in dogs with CaOx urolithiasis ( $n = 252$ ) ( $17.56 \pm 1.39$  vs  $13.16 \pm 0.47 \times 10^3$  cells/ $\mu$ L,  $P < 0.001$ ), whereas no differences were observed in other urolith types.

For serum biochemical profiles, BUN, TP, Pi, ALT, and ALP did not differ significantly among urolith types. Plasma Cr concentration was significantly higher in dogs with urate urolithiasis ( $n = 20$ ) compared with dogs with CaOx urolithiasis ( $n = 250$ ) ( $1.6 \pm 0.5$  vs  $0.8 \pm 0.1$  mg/dL,  $P < 0.01$ ). Plasma Alb concentration was also significantly higher in dogs with urate urolithiasis ( $n = 13$ ) than in dogs with CaOx urolithiasis ( $n = 183$ ) ( $3.62 \pm 1.12$  vs  $2.75 \pm 0.03$  g/dL,  $P < 0.01$ ). Although values remained within the normal range, plasma Ca concentration was significantly higher in dogs with CaOx urolithiasis ( $n = 45$ ) than in dogs with struvite urolithiasis ( $n = 18$ ) ( $10.3 \pm 0.1$  vs  $9.8 \pm 0.1$  mg/dL,  $P < 0.05$ ).

**Urinalysis results in dogs:** The mean urine pH among dogs with all urolith types ( $n = 382$ ) was  $6.3 \pm 0.1$ . Dogs with struvite urolithiasis ( $n = 71$ ) had significantly higher urine pH than dogs with CaOx urolithiasis ( $n = 184$ ) ( $6.7 \pm 0.1$  vs  $5.9 \pm 0.1$ ,  $P < 0.001$ ). The urine pH values in dogs with urate ( $n = 16$ ), cystine ( $n = 11$ ), and CaP carbonate urolithiasis ( $n = 5$ ) were  $6.4 \pm 0.3$ ,  $6.8 \pm 0.4$ , and  $6.5 \pm 0.6$ , respectively, with no significant differences compared with dogs with CaOx urolithiasis. The mean urine specific gravity among all dogs ( $n = 376$ ) was  $1.029 \pm 0.001$ , with no significant differences among urolith types.

Among the 382 dogs that underwent urinalysis, only 81 (21.2%) had detectable urinary crystals. CaOx and struvite crystals were identified across multiple urolith types. Dogs with struvite urolithiasis had significantly fewer CaOx crystals than dogs with CaOx urolithiasis (Table 4). Accordingly, CaOx crystals were detected 14.74 times more frequently in dogs with CaOx urolithiasis than in dogs with struvite urolithiasis (OR = 14.74, 95% CI = 2.35–1553.2,  $P < 0.001$ ). Similarly, struvite crystals were detected 5.44 times more frequently in dogs with struvite urolithiasis than in dogs with CaOx urolithiasis ( $P < 0.01$ ). Urate crystals were identified only in dogs with

urate urolithiasis and were detected in only 6.3% of dogs with this stone type ( $n = 16$ ). Among dogs with cystine urolithiasis ( $n = 11$ ), 9.1% had struvite crystals, whereas none had detectable cystine crystals. Urinary WBCs were identified in 77% of dogs with urolithiasis, with bacteriuria detected in some cases. Compared with dogs with CaOx urolithiasis, dogs with struvite urolithiasis were 6.45 times more likely to have pyuria ( $P < 0.001$ ), 2.41 times more likely to have bacteriuria ( $P < 0.05$ ), and 3.05 times more likely to have hematuria ( $P < 0.001$ ) (Table 4).

#### **Feline uroliths:**

**Incidence of uroliths in cats:** Between 2020 and 2024, a total of 146 feline urolith submissions were analyzed. Of these, 101 (69.2%) were CaOx, followed by 25 (17.1%) struvite, 6 (4.1%) urate, 7 (4.8%) compound, and 7 (4.8%) other urolith types (Fig. 2a). Other urolith types included cystine, brushite, CaP carbonate, CaP apatite, and osseous uroliths (Fig. 2b).

Over the 5-year study period, CaOx consistently remained the most frequently identified urolith type in cats and demonstrated an overall increasing trend, with the highest number of cases observed in 2023. Struvite remained the second most common urolith type, although its incidence declined in 2023. The incidence of urate urolithiasis fluctuated throughout the study period.

**Demographic characteristics in cats:** In cats, the highest distribution of urolithiasis was observed in Domestic Shorthair cats (DSH), accounting for 69.2% of all cases. The mean age and age at the first episode in cats with CaOx urolithiasis were significantly higher than those in cats with struvite urolithiasis ( $P < 0.01$ ) (Table 5). Cats with CaOx urolithiasis also represented the majority of recurrent cases, with a mean recurrence interval of approximately 2 years. Most uroliths were retrieved from the lower urinary tract regardless of mineral composition. Nephrolithiasis was identified in four cats, including one case each of CaOx, urate, CaP carbonate, and osseous urolithiasis. Ureterolithiasis was identified in six cats, all of which were CaOx uroliths.

**Sex and neuter status in cats:** Castrated male DSH cats showed the highest incidence of urolithiasis. No significant differences in sex or neuter status were observed among the different urolith types (Table 6).

**Table 3** Selected significant clinical signs among dogs with different urolith types compared with CaOx urolithiasis.

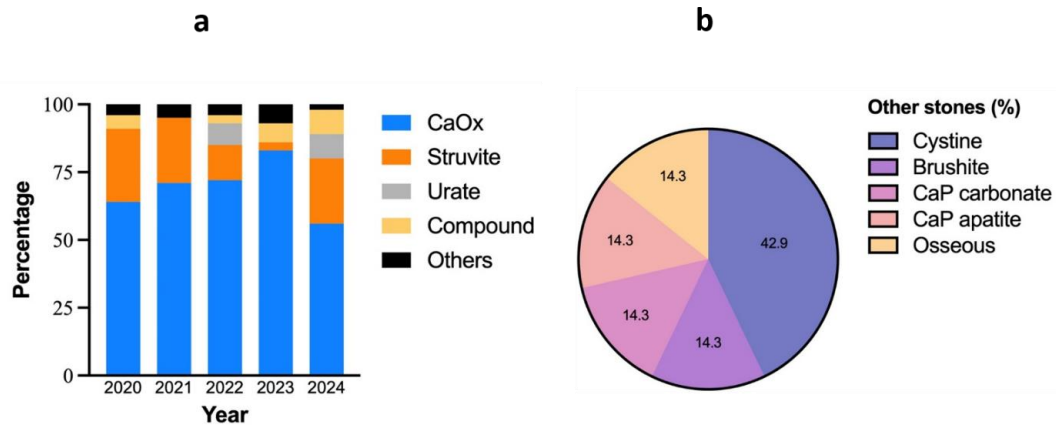
| Clinical signs | Urolith type | OR   | 95% CI     | P-value |
|----------------|--------------|------|------------|---------|
| Anorexia       | Struvite     | 2.63 | 1.17-6.40  | 0.029   |
|                | Urate        | 4.00 | 1.31-12.63 | 0.039   |
| Oliguria       | Struvite     | 0.19 | 0.07-0.52  | < 0.001 |
| Incontinence   | Struvite     | 2.10 | 1.19-3.70  | 0.015   |
| Hematuria      | Struvite     | 2.98 | 1.73-5.07  | < 0.001 |

CaOx urolithiasis was used as the reference category for odds ratio calculations. An OR > 1 indicates increased odds relative to CaOx urolithiasis. Associations were evaluated using the Fisher's exact test. CI, confidence interval; OR, odds ratio.

**Table 4** Selected significant urine sediment findings among dogs with different urolith types compared with CaOx urolithiasis.

| Urine sediment   | Urolith type | OR   | 95% CI     | P-value |
|------------------|--------------|------|------------|---------|
| CaOx crystal     | Struvite     | 0.07 | 0.01-0.41  | <0.001  |
| Struvite Crystal | Struvite     | 5.44 | 1.88-15.19 | 0.001   |
| WBC              | Struvite     | 6.45 | 3.07-13.71 | <0.001  |
| Bacteria         | Struvite     | 2.41 | 1.16-5.22  | 0.031   |
| RBC              | Struvite     | 3.05 | 1.66-5.69  | <0.001  |

CaOx urolithiasis was used as the reference category for odds ratio calculations. An OR > 1 indicates increased odds relative to CaOx urolithiasis. Associations were evaluated using the Fisher's exact test. CI, confidence interval; OR, odds ratio.

**Figure 2** Annual number of feline urolithiasis cases classified by urolith type (a) and percentage distribution of other urolith types (b) during 2020–2024.**Table 5** Demographic characteristics of cats with urolithiasis according to urolith type.

| Cats                                         | CaOx     | Struvite   | Urate   |
|----------------------------------------------|----------|------------|---------|
| Number of cases                              | 101      | 25         | 6       |
| DSH                                          | 54.5     | 56.0       | 50.0    |
| Persian                                      | 23.8     | 16.0       | 0       |
| Scottish Fold                                | 6.9      | 8.0        | 16.7    |
| Others                                       | 14.8     | 20.0       | 33.3    |
| Age (years) (101/24/5)                       | 7.2±0.4  | 4.7±0.5 †† | 6.4±1.7 |
| Age at the 1 <sup>st</sup> episode (91/24/5) | 7.2±0.4  | 4.7±0.5 †† | 6.3±1.7 |
| Recurrence (months) (10/0/0)                 | 24.2±7.6 | ND         | ND      |
| Location (100/22/4)                          |          |            |         |
| Upper                                        | 6.0      | 0          | 25.0    |
| Lower                                        | 91.0     | 100        | 75.0    |
| Both                                         | 3.0      | 0          | 0       |

Age, age at the first episode, and recurrence interval are presented as mean ± SE. Breed, sex, and anatomical location are presented as percentages. Differences among urolith types were analyzed using one-way ANOVA on ranks, with CaOx urolithiasis used as the reference group. †† $P < 0.01$ ; ND = no data. Numbers in parentheses indicate the number of cats included for each urolith type, in the order listed.

**Table 6** Associations of sex and neuter status with urolith types in cats.

|          | Intact | Neutered | P-value | Male | Female | P-value |
|----------|--------|----------|---------|------|--------|---------|
| CaOx     | 13     | 86       | 0.372   | 63   | 38     | 0.185   |
| Struvite | 5      | 19       |         | 20   | 5      |         |
| Urate    | 0      | 6        |         | 3    | 3      |         |

Associations were evaluated using Chi-square.

**Clinical signs in cats:** Clinical signs were recorded in 146 cats, with anorexia and lethargy observed in 13.0% and 10.3% of cases, respectively. The distribution of oliguria, pollakiuria, stranguria, urinary incontinence, and hematuria was 4.8%, 19.2%, 25.3%, 23.3%, and 36.3%, respectively. Cats with urate urolithiasis were

16 times more likely to present with urinary incontinence than cats with CaOx urolithiasis (OR = 16.04, 95% CI = 1.94–190.8,  $P = 0.005$ ).

**Hematology and serum biochemistry in cats:** In cats, CBC and serum biochemical parameters were within

normal ranges across all urolith types and did not differ significantly from those in cats with CaOx urolithiasis, except for WBC counts. Cats with struvite urolithiasis ( $n = 23$ ) had significantly higher WBC counts than cats with CaOx urolithiasis ( $n = 97$ ) ( $15.34 \pm 1.93$  vs  $11.11 \pm 0.53 \times 10^3$  cells/ $\mu$ L,  $P < 0.05$ ). Plasma Cr concentration in cats with struvite urolithiasis ( $n = 22$ ) tended to be higher than that in cats with CaOx urolithiasis ( $n = 95$ ) ( $4.1 \pm 1.2$  vs  $2.3 \pm 0.3$  mg/dL,  $P = 0.066$ ).

**Urinalysis results in cats:** Among all cats with urolithiasis, the mean urine pH and urine specific gravity were  $6.1 \pm 0.1$  ( $n = 105$ ) and  $1.023 \pm 0.001$  ( $n = 103$ ), respectively. Neither parameter differed significantly between cats with struvite or urate urolithiasis and those with CaOx urolithiasis. Urinary crystals were detected in only 15 of 105 cats with urolithiasis (14.3%). Both cats with CaOx and struvite urolithiasis could exhibit either CaOx or struvite crystals in urine sediment. White blood cells (WBCs) were detected in more than half of the cases regardless of urolith type. Bacteriuria and hematuria were identified in 13.3% and 67.6% of cases, respectively. No significant differences in crystal type, urinary WBCs, bacteriuria, or urinary RBCs were observed between cats with struvite or urate urolithiasis and cats with CaOx urolithiasis.

## Discussion

**Incidence of uroliths in dogs and cats:** Previous studies conducted in Thailand, which reported struvite as the most common urolith type (Hunprasit *et al.*, 2017), as well as studies from the United States (Osborne *et al.*, 2009), Mexico (Mendoza-López *et al.*, 2019), the Netherlands (Burggraaf *et al.*, 2021), and Brazil (da Silva *et al.*, 2025). However, CaOx was the most identified urolith in dogs in the present study. CaOx uroliths may be overrepresented since CaOx urolith generally lack dissolution property and require surgical management. On the other hand, lower distribution of struvite observed in the present study may partly be explained by medical management with dietary dissolution without stone submission. In addition, preventive dietary management for struvite urolithiasis has become widely implemented in Thailand, which may have contributed to a reduction in recurrent struvite cases. Urate was the third most common urolith type identified in dogs, which is consistent with previous reports (Houston *et al.*, 2017). The distribution of urate urolithiasis in the present study was 4.6%, comparable to the previously reported prevalence of 3.4% in dogs in Thailand between 2016 and 2023 (Chaysakul *et al.*, 2026). The prevalence of cystine urolithiasis varies geographically; however, a previous study in Thailand reported a prevalence of 1.6% between 2009 and 2015 (Hunprasit *et al.*, 2017), which was slightly lower than the distribution observed in the present study (2.4%).

In cats, the high distribution of CaOx urolithiasis observed in the present study is consistent with previous reports from Thailand (Hunprasit *et al.*, 2019a; Detkalaya *et al.*, 2025) and studies from other

countries (Houston *et al.*, 2016; Gerber *et al.*, 2016; Mendoza-López *et al.*, 2019; Burggraaf *et al.*, 2021). In contrast, one study from Brazil reported struvite as the most common feline urolith type (da Silva *et al.*, 2025). This variation may partly be influenced by dietary factors. Previous studies have shown that feline diets low in sodium or potassium, as well as diets formulated to promote acidic urine, are associated with an increased risk of CaOx urolith formation and a decreased risk of struvite urolithiasis (Lekcharoensuk *et al.*, 2001). Similar to dogs, urate was the third most common urolith type identified in cats, accounting for 4.1% of all feline uroliths. The distribution of cystine urolithiasis in cats was 2.1%, which was slightly higher than the previously reported prevalence in Thailand (0.8%) between 2010 and 2017 (Hunprasit *et al.*, 2019a).

**Breeds:** Breed predisposition was evident in the present study. Small-breed dogs had a significantly higher risk of CaOx urolithiasis compared with medium-breed dogs. In contrast, medium-breed dogs, particularly Bulldogs and Welsh Corgis, had a higher risk of developing urate and cystine urolithiasis than small-breed dogs. Small-breed dogs such as Pomeranians, Chihuahuas, Shih Tzus, Yorkshire Terriers, and Poodles are among the most popular companion dog breeds in Thailand, which may partly explain their high representation in the present study. Previous studies have reported increased risk of CaOx urolithiasis in breeds including Cairn Terriers, Chihuahuas, Miniature Schnauzers, Jack Russell Terriers, Maltese, Papillons, and Yorkshire Terriers, whereas Bernese Mountain Dogs, Dachshunds, Golden Retrievers, Labrador Retrievers, Pugs, and Shih Tzus were reported to have a higher risk of struvite urolithiasis (Lekcharoensuk *et al.*, 2000a; Houston *et al.*, 2017; Burggraaf *et al.*, 2021).

Unlike CaOx and struvite uroliths, cystine and urate uroliths were predominantly identified in Bulldogs and Bulldog-related breeds, which is consistent with previous studies demonstrating strong breed-associated risk for these urolith types (Bartges *et al.*, 1994; Burggraaf *et al.*, 2021; Chaysakul *et al.*, 2026). However, Bulldogs were not included in the cystinuria classification system based on inheritance pattern, gene mutation, and androgen sensitivity, which categorizes cystinuria into Type I-A, Type II-A, Type II-B, and Type III (Brons *et al.*, 2013). Previous reports identified high risk of cystine urolithiasis in breeds such as Mastiffs, Newfoundlands, Scottish Deerhounds, Basenjis, Chihuahuas, Bulldogs, French Bulldogs, English Bulldogs, Miniature Pinschers, Rottweilers, and Dachshunds (Houston *et al.*, 2017). Increased incidence of cystine urolithiasis compared with struvite urolithiasis has also been reported in American Staffordshire Terriers, Staffordshire Bull Terriers, Basset Hounds, and Miniature Pinschers (Burggraaf *et al.*, 2021). In the present study, some Bulldogs and all Dalmatians developed urate urolithiasis, which is consistent with previous reports (Defarges *et al.*, 2020; Burggraaf *et al.*, 2021). Kopečný *et al.* (2021a) reported that Dalmatians, Bulldogs, and English Bulldogs had 85.5-, 7.8-, and 5.6-fold greater

risk, respectively, of developing urate urolithiasis compared with mixed-breed dogs. In Dalmatians, defective hepatic uric acid transport results in hyperuricosuria and urine supersaturation with urate, predisposing affected dogs to urate urolith formation. Urolith-forming Dalmatians, Bulldogs, and Black Russian Terriers have been shown to be homozygous for mutations in the *SLC2A9* gene (Defarges *et al.*, 2020). Sequence and expression analyses of the *SLC2A9* gene identified one missense mutation (G616T;C188F) and two promoter mutations. The missense mutation is associated with hyperuricosuria in Dalmatians, whereas the promoter SNPs are also present in unaffected dog breeds (Bannasch *et al.*, 2008). In addition, urate urolithiasis is more common in dogs with portosystemic shunts (Defarges *et al.*, 2020). English Cocker Spaniels have also been reported to have increased risk of urate urolithiasis (Burggraaf *et al.*, 2021), although this breed was not represented in the present study. This discrepancy may reflect differences in breed popularity and geographic distribution, as well as the relatively small sample size of the present study.

Most cats with urolithiasis in the present study were DSH cats, which is consistent with previous findings (Burggraaf *et al.*, 2021) and likely reflects the high population of DSH cats in Thailand. Previous studies have reported lower incidence of struvite urolithiasis, using CaOx as the reference group, in British Shorthair, British Longhair, Birman, Maine Coon, Persian Longhair, and Ragdoll cats compared with DSH cats (Burggraaf *et al.*, 2021). However, these breeds are relatively uncommon in Thailand.

**Age:** Dogs with CaOx urolithiasis exhibited the highest mean age at the first episode (9.2 years), which was significantly higher than that observed in dogs with struvite (7.6 years), urate (5.9 years), and cystine urolithiasis (4.4 years). This age distribution pattern is consistent with previous reports demonstrating that CaOx urolithiasis predominantly affects older dogs, whereas cystine urolithiasis tends to occur in young to middle-aged dogs, typically between 4 and 6 years of age (Kovářiková *et al.*, 2021). The mean age of dogs with urate urolithiasis in the present study was approximately 5.7 years, which is comparable to previous reports from the Netherlands (5.9 years) (Burggraaf *et al.*, 2021) and Thailand (6.07 years) (Chaysakul *et al.*, 2026).

In cats, the mean age at the first episode of CaOx urolithiasis was significantly higher than that of struvite urolithiasis (7.2 vs. 4.7 years) and was slightly lower than that observed in dogs. Similar findings have been reported previously, in which the proportion of CaOx urolithiasis was higher and struvite urolithiasis was lower in cats older than 7 years compared with cats  $\leq 7$  years of age (Detkalaya *et al.*, 2025). Most animals in the present study experienced urolithiasis as the first episode. The mineral composition of uroliths appears to be closely associated with age at onset, likely reflecting differences in the metabolic, genetic, and hormonal mechanisms involved in stone formation.

**Recurrence interval:** CaOx urolithiasis showed the longest recurrence interval, averaging more than 3 years in dogs and approximately 2 years in cats. Previous studies reported recurrence rates of CaOx urolithiasis ranging from 48–57% within 3 years in dogs and 7.1% within 2 years in cats (Albaskan *et al.*, 2009). In the present study, dogs with urate urolithiasis exhibited recurrence within approximately 1 month after the previous episode. This short recurrence interval likely reflects the strong metabolic and genetic predisposition associated with urate stone formation, particularly in breeds with inherited abnormalities in purine metabolism and uric acid transport. These findings highlight the importance of long-term medical management and dietary control in dogs with urate urolithiasis to reduce the risk of early recurrence.

**Location:** Most uroliths in both dogs and cats were located in the lower urinary tract, particularly in the urinary bladder, which is consistent with previous reports (Burggraaf *et al.*, 2021; da Silva *et al.*, 2025). In the present study, the upper urinary tract stone in both dogs and cats were composed of CaOx, urate, struvite and other types. Previous studies reported that the most common mineral compositions of nephroliths were CaOx and struvite in dogs (Kopečný *et al.*, 2021a), and CaOx and apatite in cats (Kopečný *et al.*, 2021b). Hyperoxaluria is considered one of the primary risk factors for renal CaOx urolithiasis in humans, dogs, and cats, although multiple additional factors may also contribute. Calcium oxalate nephrolithiasis in dogs and cats is commonly observed in older neutered males of specific breeds. Other contributing risk factors include hormonal and metabolic abnormalities affecting calcium and vitamin D metabolism, urine supersaturation, dietary composition, and the balance between promoters and inhibitors of crystal formation and stone growth within the kidneys (O’Kell *et al.*, 2017).

**Sex and neuter status:** Sex distribution in dogs in the present study demonstrated a marked predominance of intact males across all urolith types. This observation may be explained by a combination of hormonal influences on mineral metabolism and anatomical characteristics of the male urinary tract. In human patients with urolithiasis, male stone formers have been reported to exhibit higher serum testosterone concentrations than individuals without urolithiasis (Watson *et al.*, 2010). The present study also demonstrated that female dogs had a higher risk of developing struvite urolithiasis compared with CaOx urolithiasis. This finding is consistent with a previous report from the Netherlands (Burggraaf *et al.*, 2021). Female dogs are predisposed to urinary tract infections because their urethra is shorter and wider than that of males, facilitating ascending bacterial infection and subsequent struvite stone formation. All cystine uroliths identified in the present study were retrieved from male dogs, which is consistent with previous findings showing a higher prevalence of cystine urolithiasis in males than females (Burggraaf *et al.*, 2021). Defective renal tubular transport of amino acids,

particularly cystine, is the primary cause of cystine urolithiasis, whereas Type III cystinuria is predominantly observed in mature intact male dogs because of its androgen-dependent nature (Brons *et al.*, 2013). In addition, the longer and narrower male urethra increases the likelihood of urinary obstruction, potentially leading to earlier clinical recognition and surgical intervention, which may contribute to the higher apparent prevalence of urolithiasis in male dogs.

No significant association between sex and neuter status among feline urolith types was observed in the present study, which is consistent with a previous report showing no relationship between sex and either MAP or CaOx urolithiasis (Detkalaya *et al.*, 2025). Most uroliths in the present study were identified in castrated male DSH cats, which represented the largest population across all urolith types. This finding may partly reflect the high proportion of neutered cats in Thailand due to population control practices. However, previous studies have reported a higher incidence of struvite urolithiasis in female cats (Lekcharoensuk *et al.*, 2000b; Burggraaf *et al.*, 2021) and a higher incidence of CaOx urolithiasis in neutered cats of both sexes (Burggraaf *et al.*, 2021). Neutered cats may have increased risk of urolithiasis because of hormonal changes as well as a greater tendency toward obesity and reduced physical activity (Gomes *et al.*, 2018; Hunprasit *et al.*, 2019b). In humans, overweight individuals with urolithiasis have been reported to exhibit hyperoxaluria and reduced urinary citrate excretion, both of which may predispose to stone formation (Sarica *et al.*, 2008).

**Clinical signs in dogs and cats:** Clinical signs associated with lower urinary tract dysfunction, including stranguria, pollakiuria, and hematuria, were observed across all urolith types. The clinical presentation of urolithiasis was generally nonspecific and could not reliably distinguish among different urolith types. The overlap in clinical manifestations likely reflects shared pathophysiological mechanisms, including mechanical irritation of the urinary tract and partial or complete urinary obstruction. A previous study reported that 65.97% of affected animals presented with hematuria, whereas the remaining cases had a history of urinary tract infection (da Silva *et al.*, 2025). In the present study, dogs with struvite urolithiasis showed higher incidence of urinary incontinence and hematuria compared with dogs with CaOx urolithiasis. Infection with urease-producing bacteria may contribute to mucosal inflammation and irritation of the urinary tract epithelium, resulting in increased bleeding and more pronounced hematuria in cases of struvite urolithiasis. In cats, however, only urinary incontinence was more common in cats with urate urolithiasis than in cats with CaOx urolithiasis, which may be associated with urinary tract obstruction.

**Hematology and serum biochemistry in dogs and cats:** most hematologic and serum biochemical parameters were within reference ranges across all urolith types in

both dogs and cats, suggesting that urolithiasis may not produce marked systemic abnormalities at the time of presentation. This finding is consistent with previous report (Langston *et al.*, 2008). Hematologic findings in lower urinary tract urolithiasis are often variable and nonspecific for diagnosis (Yayingül, 2024). Nevertheless, significantly higher WBC counts were observed in dogs and cats with struvite urolithiasis compared with those with CaOx urolithiasis, although WBC counts in cats remained within the reference range. The leukocytosis observed in dogs with struvite urolithiasis is consistent with the well-established association between struvite stone formation and bacterial urinary tract infection (Palma *et al.*, 2013).

Small-breed dogs constituted the majority of CaOx urolith submissions and tended to have higher serum Ca concentrations. However, the plasma Ca concentrations were within normal reference range and may not be clinically relevant. Previous study showed that hypercalciuria resulting from excessive intestinal Ca absorption, impaired renal tubular Ca reabsorption or increased bone resorption, may increase the risk of CaOx stone formation (Bartges and Corbee, 2023). Dogs with CaOx urolithiasis may exhibit either normocalcemia or hypercalcemia accompanied by increased urinary Ca excretion, which has been associated with the rs852900542 mutation of the vitamin D receptor gene (Chamsuwan *et al.*, 2021). In cats, plasma Ca concentration did not differ among urolith types in the present study, which is consistent with previous findings in cats with CaOx urolithiasis (Jewell *et al.*, 2022). Furthermore, although 35% of cats with idiopathic hypercalcemia reportedly had urolithiasis, only 10% of these cases were associated with CaOx uroliths (Midkiff *et al.*, 2000). In the present study, dogs with urate urolithiasis had higher plasma Alb concentrations than dogs with CaOx urolithiasis. The reason for the increased plasma Alb concentration in dogs with urate urolithiasis remains unclear, although low serum Alb has been reported as a risk factor for urate stone formation in humans (Wang *et al.*, 2024). Azotemia was identified in three dogs with urate urolithiasis and may have been associated with urinary tract obstruction. Two cases involved male Dalmatians and Bulldogs with uroliths located in the urinary bladder, whereas the third case was a female Jack Russell with ureterolithiasis. In cats, 7 from the 25 cats with struvite urolithiasis had a urinary tract obstruction leading to azotemia. This aligns with report that feline urethral plugs consist predominantly of struvite (Osborne *et al.*, 2009).

**Urinalysis results in dogs and cats:** Urine pH was closely associated with urinary tract infection. In the present study, urine pH was significantly higher in dogs, but not in cats, with struvite urolithiasis compared with those with CaOx urolithiasis. Struvite crystals and uroliths preferentially form in alkaline urine, often secondary to infection with urease-producing bacteria that increase urinary pH through ammonia production (Seaman and Bartges, 2001; Palma *et al.*, 2013), thereby reducing the solubility of

MAP. Increased urinary WBCs, bacteriuria, and hematuria, together with leukocytosis and clinical signs of voiding dysfunction, are suggestive of urinary tract infection in dogs with struvite urolithiasis. However, the urine culture was not performed in all cases to confirm the association in this study.

In the present study, urinary WBCs and RBCs were detected in more than half of cats with urolithiasis; however, no significant differences were observed among urolith types. A previous study reported positive urine cultures in 41.5% of overall feline urolithiasis cases and in 62.1% of cats with struvite urolithiasis (Detkalaya *et al.*, 2025). Furthermore, 58.3% of cats with struvite urolithiasis had positive urine cultures for strong urease-producing bacteria, which increased the risk of MAP by 11.93 times compared with CaOx. Identified bacteria included *Escherichia coli*, *Klebsiella* spp., *Staphylococcus* spp., *Enterococcus* spp., *Proteus* spp., *Pseudomonas* spp., *Streptococcus* spp., *Acinetobacter* spp., and *Pasteurella* spp. (Detkalaya *et al.*, 2025).

Urine in both dogs and cats was not concentrated, with no significant differences in urine specific gravity among urolith types compared with CaOx urolithiasis. Nevertheless, previous studies have suggested that reduced water intake contributes to urolith formation (Gomes *et al.*, 2018).

Crystalluria was inconsistently observed, being detected in only 21.2% of dogs and 14.3% of cats with urolithiasis. Both CaOx and struvite crystals were identified across multiple urolith types, indicating that the presence of urinary crystals cannot reliably predict either the presence or composition of uroliths. However, in dogs, CaOx crystals were detected 14.74 times more frequently in dogs with CaOx urolithiasis than in dogs with struvite urolithiasis, whereas struvite crystals were detected 5.44 times more frequently in dogs with struvite urolithiasis than in dogs with CaOx urolithiasis. Although crystalluria cannot definitively identify urolith type, it may serve as a supportive tool for predicting urolith composition in dogs. In cats, no significant differences in crystal type were observed between CaOx and struvite urolithiasis, suggesting that crystalluria alone is insufficient for determining stone composition and emphasizing the limited diagnostic value of urine sediment examination for definitive urolith typing in cats.

Cystine crystals were rarely observed in the present study. Although detection of cystine crystals strongly suggests cystinuria, cystine crystalluria is not consistently present in dogs with cystine urolithiasis or cystinuria (Osborne *et al.*, 1999). This finding supports previous reports highlighting the limited diagnostic utility of crystalluria for urolith typing and reinforces the importance of quantitative urolith analysis.

This study has several limitations. The data were obtained primarily from dogs and cats that underwent surgical removal of uroliths at the Small Animal Teaching Hospital, Chulalongkorn University, which may not fully represent the overall canine and feline populations in Thailand. In addition, some data were incomplete because of missing information in hospital records. Some animals may also have had concurrent

systemic diseases that could influence clinical signs and laboratory findings. Compound and mixed uroliths were not analyzed separately because of the limited number of cases. The breed comparison were simplified into small- and medium-sized groups without adjustment for breed popularity in the general hospital population. As small breed such as Pomeranians and Chihuahuas are common breeds in Thailand, the reported odd ratios may partly reflect breed popularity rather than true biological predisposition. Furthermore, most analyses included all cases regardless of recurrence status. Therefore, some observed associations may have been influenced by dietary modification, owner awareness, medical management, and other interventions implemented between recurrent episodes. Dietary information, one of the major determinants of urolith formation, was lacking, which may have influenced the distribution of urolith types in the present study. Besides, the urine culture was not performed in all cases to confirm urinary tract infection.

In conclusion, CaOx and struvite were the most common urolith types identified in the lower urinary tract of old-aged male small-breed dogs and DSH cats. Age at the first episode, recurrence interval, and several laboratory findings differed among urolith types. Although clinical signs and routine laboratory findings were generally nonspecific, evaluation of plasma Ca concentration, WBC count, and urine pH in dogs may provide additional clinical value in the assessment of urolithiasis. In cats, azotemia was observed in some cases and may be associated with urinary tract obstruction. These findings provide useful information for the diagnosis and long-term management of canine and feline urolithiasis.

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## References

- Albasan H, Osborne CA, Lulich JP, Lekcharoensuk C, Koehler LA, Ulrich LK and Swanson LL 2009. Rate and frequency of recurrence of uroliths after an initial ammonium urate, calcium oxalate, or struvite urolith in cats. *J Am Vet Med Assoc.* 235: 1450-1455.
- Bannasch D, Safra N, Young A, Karmi N, Schaible RS and Ling GV 2008. Mutations in the SLC2A9 gene cause hyperuricosuria and hyperuricemia in the dog. *PLoS Genet.* 4: e1000246.
- Bartges JW and Corbee RJ 2023. Nutritional management of lower urinary tract disease. In: *Applied Veterinary Clinical Nutrition*. 2nd ed. AJ Fascetti, SJ Delaney, JA Larsen and C Villaverde (eds). Hoboken, NJ: John Wiley & Sons, Inc. 412-440.
- Bartges JW, Osborne CA, Lulich JP, Unger LK, Koehler LA, Bird KA, Clinton CW and Davenport MP 1994. Prevalence of cystine and urate uroliths in bulldogs and urate uroliths in dalmatians. *J Am Vet Med Assoc.* 204: 1914-1918.
- Brons AK, Henthorn PS, Raj K, Fitzgerald CA, Liu J, Sewell AC and Giger U 2013. SLC3A1 and SLC7A9 mutations in autosomal recessive or dominant canine cystinuria: A new classification system. *J Vet Intern Med.* 27: 1400-1408.
- Burggraaf ND, Westgeest DB and Corbee RJ 2021. Analysis of 7866 feline and canine uroliths submitted between 2014 and 2020 in the Netherlands. *Res Vet Sci.* 137: 86-93.
- Chamsuwan S, Angkanaporn K, Dissayabutra T, Chuaypen N and Buranakarl C 2021. The association between single nucleotide polymorphism in vitamin D receptor and calcium oxalate urolithiasis in dogs. *J Vet Intern Med.* 35: 2263-2270.
- Chaysakul N, Lulich JP and Hunprasit V 2026. Epidemiologic evaluation of canine urate urolithiasis in Thailand: A comparative cross-sectional study between 2016-2023. *Thai J Vet Med.* 56(2): 4.
- da Silva WC, Rocha BCA, Castro SV, Belo TS, Sousa CEL, Serruya FJD and Camargo-Júnior RNC 2025. Retrospective study of 353 confirmed cases of urolithiasis in dogs and cats treated at veterinary clinics in the northern region of Pará, Brazil. *Braz J Vet Med.* 47: e005624.
- Defarges A, Evason M, Dunn M and Berent A 2020. Urolithiasis in small animals. In: *Clinical Small Animal Internal Medicine*. DS Bruyette (ed). Hoboken, NJ: John Wiley & Sons, Inc. 1123-1156.
- Detkalaya O, Kornkasem S, Vichukit K, Suksamranthaweerat M and Aponrat P 2025. Association between uropathogens and the occurrence of magnesium ammonium phosphate and calcium oxalate in cats with urolithiasis: A retrospective study (2016-2021). *J Feline Med Surg.* 27: doi:10.1177/1098612X251320246.
- Gerber B, Brandenberger-Schenk F, Rothenanger E and Müller C 2016. Uroliths of cats in Switzerland from 2002 to 2009. *Schweiz Arch Tierheilkd.* 158: 711-716.
- Gomes VDR, Ariza PC, Borges NC, Schulz Junior FJ and Fioravanti MCS 2018. Risk factors associated with feline urolithiasis. *Vet Res Comm.* 42: 87-94.
- Houston DM, Vanstone NP, Moore AE, Weese HE and Weese JS 2016. Evaluation of 21 426 feline bladder urolith submissions to the Canadian Veterinary Urolith Centre (1998-2014). *Can Vet J.* 57: 196-201.
- Houston DM, Weese HE, Vanstone NP, Moore AE and Weese JS 2017. Analysis of canine urolith submissions to the Canadian Veterinary Urolith Centre, 1998-2014. *Can Vet J.* 58: 45-50.
- Hunprasit V, Osborne CA, Schreiner PJ, Bender JB and Lulich JP 2017. Epidemiologic evaluation of canine urolithiasis in Thailand from 2009 to 2015. *Res Vet Sci.* 115: 366-370.
- Hunprasit V, Pusoonthornthum P, Koehler L and Lulich JP 2019a. Epidemiologic evaluation of feline urolithiasis in Thailand from 2010 to 2017. *Thai J Vet Med.* 49(1): 101-105.
- Hunprasit V, Tanrattana C and Pengpis S 2019b. Epidemiology of characteristics and risk factors for overweight in cats visiting an animal hospital in Bangkok, Thailand. *Thai J Vet Med.* 49(2): 107-111.
- Jewell DE, Tavener SK, Hollar RL and Panickar KS 2022. Metabolomic changes in cats with renal disease and calcium oxalate uroliths. *Metabolomics* 18: 68.
- Kopecny L, Palm CA, Segev G and Westropp JL 2021a. Urolithiasis in dogs: Evaluation of trends in urolith composition and risk factors (2006-2018). *J Vet Intern Med.* 35: 1406-1415.
- Kopecny L, Palm CA, Segev G, Larsen JA and Westropp JL 2021b. Urolithiasis in cats: Evaluation of trends in urolith composition and risk factors (2005-2018). *J Vet Intern Med.* 35: 1397-1405.
- Kovářiková S, Maršálek P and Vrbová K 2021. Cystinuria in dogs and cats: What do we know after almost 200 years? *Animals* 11: 2437.
- Langston C, Gisselman K, Palma D and McCue J 2008. Diagnosis of urolithiasis. *Compend Contin Educ Vet.* 30: 447-455.
- Lekcharoensuk C, Lulich JP, Osborne CA, Pusoonthornthum R, Allen TA, Koehler LA, Ulrich LK, Carpenter KA and Swanson LL 2000a. Patient and environmental factors associated with calcium oxalate urolithiasis in dogs. *J Am Vet Med Assoc.* 217: 515-519.
- Lekcharoensuk C, Lulich JP, Osborne CA, Pusoonthornthum R, Allen TA, Koehler LA, Ulrich LK, Carpenter KA and Swanson LL 2000b. Association between patient-related factors and risk of calcium oxalate and magnesium ammonium phosphate urolithiasis in cats. *J Am Vet Med Assoc.* 217: 520-525.

- Lekcharoensuk C, Osborne CA, Lulich JP, Pusoonthornthum R, Kirk CA, Ulrich LK, Koehler LA, Carpenter KA and Swanson LL 2001. Association between dietary factors and calcium oxalate and magnesium ammonium phosphate urolithiasis in cats. *J Am Vet Med Assoc.* 219: 1228–1237.
- Mendoza-López CI, Del-Angel-Caraza J, Aké-Chiñas MA, Quijano-Hernández IA and Barbosa-Mireles MA 2019. Epidemiology of urolithiasis in dogs from Guadalajara City, Mexico. *Vet Mex.* 6: 9-22.
- Midkiff AM, Chew DJ, Randolph JF, Center SA and DiBartola SP 2000. Idiopathic hypercalcemia in cats. *J Vet Intern Med.* 14: 619–626.
- Monnet E and Kyles A 2023. Urolithiasis of the lower urinary tract. In: *Small Animal Soft Tissue Surgery*. 2nd ed. E Monnet (ed). Hoboken, NJ: John Wiley & Sons, Inc. 523-532.
- O’Kell AL, Grant DC and Khan SR 2017. Pathogenesis of calcium oxalate urinary stone disease: Species comparison of humans, dogs, and cats. *Urolithiasis.* 45: 329–336.
- Osborne CA, Lulich JP, Kruger JM, Ulrich LK and Koehler LA 2009. Analysis of 451,891 canine uroliths, feline uroliths, and feline urethral plugs from 1981 to 2007: Perspectives from the Minnesota Urolith Center. *Vet Clin North Am Small Anim Pract.* 39: 183–197.
- Osborne CA, Sanderson SL, Lulich JP, Bartges JW, Ulrich JK, Koehler LA, Bird KA and Swanson LL 1999. Canine cystine urolithiasis. Cause, detection, treatment, and prevention. *Vet Clin North Am Small Anim Pract.* 29: 193–211.
- Palma D, Langston C, Gisselman K and McCue J 2013. Canine struvite urolithiasis. *Compend Contin Educ Vet.* 35: E1.
- Sarıca K, Altay B and Erturhan S 2008. Effect of being overweight on stone-forming risk factors. *Urology* 71: 771-777.
- Seaman R and Bartges J 2001. Canine struvite urolithiasis. *Compend Contin Educ Vet.* 23: 407-420.
- Ulrich LK, Bird KA, Koehler LA and Swanson L 1996. Urolith analysis. Submission, methods, and interpretation. *Vet Clin North Am Small Anim Pract.* 26: 393-400.
- Wang Y, Zhu Y, Luo W, Long Q, Fu Y and Chen X 2024. Analysis of components and related risk factors of urinary stones: a retrospective study of 1055 patients in southern China. *Sci Rep.* 14: 28357.
- Watson J, Shrewsbury A, Taghechian S, Goodman M, Pattaras J, Ritenour C and Ogan K 2010. Serum testosterone may be associated with calcium oxalate urolithogenesis. *J Endourol.* 24: 1183–1187.
- Yaygingül R 2024. Clinical, laboratory, radiography and ultrasonography findings and surgical treatment the lower urinary system urolithiasis in cats and dogs. *Anim Health Prod Hyg.* 13: 23–30.