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Original

Canine struvite urolithiasis: Epidemiological and clinical characteristics in Mexico

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ABSTRACT

Objective. Identify demographic risk factors and clinical characteristics of struvite urolithiasis (UEs) in a canine population from Mexico. Animals. Dog cases with struvite urolith from the urolith analysis laboratory from 2012-2017. **Materials and methods.** A comparative cross-sectional study was conducted to identify demographic risk factors in dogs with UEs by comparing cases between two groups. Description of the clinical characteristics, they will be used in clinical data of dogs with UEs. Statistical analysis included X^2 test, odds ratio (OR) and confidence interval (95% CI). Significant values were considered with $p<0.05$. Multivariate logistic regression analysis was used to identify association between factors. **Results.** The UEs frequency was 41.2% and female dogs were greater odds at for developing this urolithiasis ($p<0.05$; $p <0.001$) across all comparison groups, as well as the small-size animals ($p<0.01$) with respect to large-sized ones. Associations between a struvite urolithiasis diagnosis and individual breeds and age were identified. The clinical characteristics found were urine pH ≥7, specific gravity ≥1.025, presence of moderately radiopacity uroliths ≥30 mm and solitary into the bladder in female. Recurrence was more frequently between the first and second year (56.7%). **Conclusions**: The identification of these demographic factors and the knowledge of clinical characteristics will allow veterinarians to predict that the urolith composition is struvite and consider medical dissolution as treatment.

Keywords: Epidemiology; struvite; uroliths; Mexico (*Source: USA National Library of Medicine*).

RESUMEN

Objetivo. Identificar factores de riesgo demográficos y características clínicas de la urolitiasis de estruvita en perros de México. Animales. Casos clínicos de perros con urolitiasis de estruvita obtenidos de la base de datos del laboratorio de análisis de urolitos del 2012-2017. **Materiales y Métodos**. Se realizó un estudio transversal comparativo para identificar factores de riesgo demográficos mediante la comparación de casos entre dos grupos. En la descripción de las características clínicas se utilizaron

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datos clínicos de los casos. El análisis estadístico incluyó prueba de X^2, razón de probabilidades (OR) e intervalo de confianza del 95%, considerando como valor significativo una $p<0.05$. El análisis de regresión logística multivariada se utilizó para identificar asociación entre factores. **Resultados**. La frecuencia de la urolitiasis de estruvita fue del 41.2%. Las hembras tuvieron mayor probabilidad de desarrollar esta urolitiasis ($p<0.05$; $p<0.001$) en todos los grupos de comparación, asi como los animales de talla pequeña ($p<0.01$) con respecto a los de talla grande. Asociaciones entre un diagnóstico de urolitiasis de estruvita y las razas individuales y edad fueron identificadas. Las características clínicas encontradas fueron pH urinario ≥7, densidad urinaria ≥1.025, presencia de urolitos moderadamente radiopacos ≥30 mm y únicos en vejiga de las hembras. La recurrencia fue más frecuente entre el primer y segundo año (56.7%). **Conclusiones**: La identificación de los factores demográficos y de las características clínicas ayudará a los clínicos veterinarios a predecir la composición mineral del urolito de estruvita, y así poder considerar la disolución médica como tratamiento.

Palabras clave: Estruvita; epidemiología; urolitos; México (*Fuente: USA National Library of Medicine*).

INTRODUCTION

Urolithiasis is a chronic and often recurrent disease that affects different animal species. In dogs, it represents approximately 18% of caudal urinary tract diseases in veterinary teaching hospitals in the United States and 20% in Mexico (1). This disease is manifested by the presence of uroliths at any site of the urinary tract, where different genetic, congenital or acquired factors are involved, increasing the risk of precipitation of metabolites excreted in the urine to form uroliths (2).

Several epidemiological studies carried out in reference laboratories have described that struvite and calcium oxalate uroliths represent more than 80% of samples analyzed in dogs (3,4,5). With regard to struvite urolithiasis (SU), a global study reported a frequency of 41.9% (3); in some European countries from 32.9 to 68.8% (4,6,7,8) and from 47 to 53.4% in America (9,10,11). Specifically in Mexico, SU has been described in cities such as Mexico City and Guadalajara, with frequencies of 38.1% and 44.1%, respectively (1,12).

In dogs, the pathophysiology of SU is associated with the presence of urinary tract infections caused by urease-positive bacteria, and sterile struvite is not commonly recognized. In addition, demographic factors such as breed, sex and age may influence this type of urolithiasis (2). Studies have been conducted in different geographic areas of North America (9,11,13) to identify these factors, but they may not be applicable in Mexico due to differences in geography, diet, and breed popularity in each region.

Since struvite is one of the most frequent uroliths, and there is no epidemiological data on its pathology in Mexico, this study was performed with the aim of identifying demographic risk factors and clinical characteristics of a dog population with SU from urolith samples analyzed in the Urolith Analysis Laboratory of the Veterinary Hospital for Small Species of the Faculty of Veterinary Medicine of the Autonomous University of the State of Mexico (UAL-UAEMex).

MATERIALS AND METHODS

SU cases. Records of pure-breed dogs with SU were selected from the UAL-UAEMex database from January 2012 to December 2017, including only cases where the analyzed samples had >70% struvite in their quantitative analysis. Records of 224 cases of dogs with SU were selected from the database.

Comparison groups. Two comparison groups were used as controls to identify demographic risk factors.

Hospital group (HCG). Pure-breed dogs that came to the clinic during the same period as the SU cases were selected randomly from the medical records in University Hospital data base.

Animals undergoing preventive medicine clinical care, with a history of clinical signs of urinary disease, or fed therapeutic urolithiasis diets, were excluded. To increase the power of the study, four HCG animals per case were selected as controls (4:1 ratio). As an official canine population census is not available in Mexico, hospital controls were used as the reference population to calculate the odds ratios (ORs) for sex, breed, and age (14). According to these criteria, 896 dogs were chosen from this group.

Dogs with other urolith types group (OUCG). Pure-breed dogs that presented with urolith types other than struvite were selected from the UAL-UAEMex database. Dogs with mixed or compound uroliths having <70% struvite in their mineral composition were excluded from this group. The ratio of control dogs in this group with respect to the cases was 1.4:1. During this period, 612 uroliths from dogs were analyzed. Of this population, 52 were from mixed-breed dogs and 22 had mixed and/or compound uroliths. These cases were excluded from the final OUCG. However, these data were used to calculate the struvite frequency in our laboratory during this period. From a total of 538 pure-breed dogs with urolithiasis and without the presence of mixed and/or compound uroliths, 314 dogs that showed other urolith types were chosen.

Variables. Epidemiological information was obtained from our data base: 80.0% of SU came from the central region of the country and the rest from other regions. Patient data such as race, height, age, sex, location of the urolith within the urinary tract, urine pH, urine specific gravity (USG), the number of previous episodes of urolithiasis, and type of commercial or homemade diet were considered for this study. The animals were classified into three age groups: 0–5 years; 6–10 years and >10 years. Only pure-breed animals were chosen. Regarding the size of the dog, all small or miniature breeds listed by the American Kennel Club were considered "small", and all remaining breeds were considered "large" (11). HCG breed, size, sex, and age were obtained from the medical admission records of our hospital.

Analysis of uroliths. The physical characteristics, such as shape, color, appearance, size, weight, and number of uroliths per patient of each sample received for analysis, were described. Stereoscopic microscopy (Stemi DV4 Stereomicroscope, Zeiss, USA) was used to examine the internal architecture of uroliths if they had a diameter of >5 mm and could be cut in half to differentiate the internal layers: nucleus, stone, cortex or shell, and/or surface crystals and to enable analysis of each layer (Figure 1). For uroliths of <5 mm in size, a single test was performed after crushing the entire urinary stone into a fine powder. The uroliths were classified according to the amount of mineral they contained; they were considered as "pure" when they had more than 70% of a single mineral, "mixed" with less than 70% of a single mineral and "compound" when the urolith had layers of different mineral composition (1). The uroliths' chemical compositions were determined by infrared spectroscopy (FT-IR Spectrum 2, PerkinElmer, USA) with a diamond ATR. For the quantitative analysis of the different minerals, an electronic reference library of spectra (NICODOM IR Kidney stones 1668 spectra Nikodom, Czech Republic) was used.

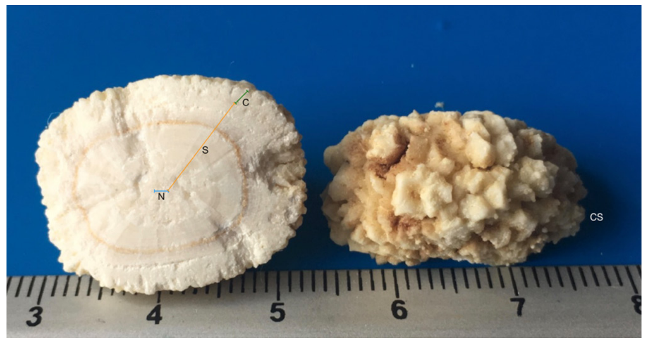

Figure 1. Struvite urolith layers. N = nucleus or nidus, S = stone or body, C = cortex or shell, CS = surface crystals.

***In vitro* radiographic studies**. *In vitro* radiography was performed to evaluate the degree of radiopacity of the struvite uroliths. The first image consisted of an X-ray of struvite uroliths immersed in a saline solution inside a Petri dish. In the second image, a piece of fresh pork meat of 5 cm thickness was used to simulate contrast with soft tissues. Struvite uroliths of different sizes and shapes were used (Figure 2).

Statistical analysis. The data were entered into a spreadsheet and were descriptive. Calculations were made with the assistance of GraphPad Prism 6.0 software.

Preliminary univariate analysis of the assumed demographic risk factors of SU was performed. The ORs were used as a measure of association between the independent variables and results of interest. An OR of <1 was indicative of protective effects, while an OR of >1 indicated a greater risk and was considered statistically significant with a p-value of <0.05 (14). The importance of univariate associations was determined using the χ^2 test. Only exposures with a p-value of <0.20 were included in the multivariate logistic regression model in Sigma Plot software (http://www.sigmaplot.co.uk).

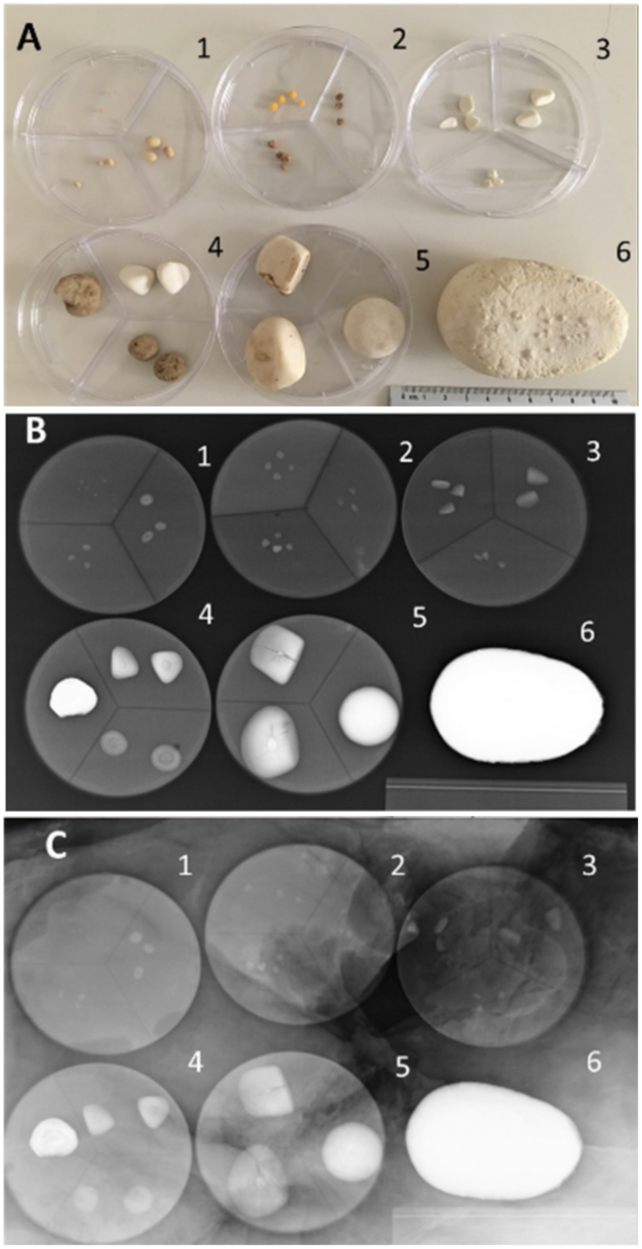

Figure 2. Different sizes and shapes of struvite uroliths (A), their radiographic characteristics in samples with liquid (B), and with soft tissue contrast (C). 1– oval uroliths of 1–3 mm; 2 – round uroliths of 2–4 mm; 3 – pyramidal uroliths of 3–5 mm; 4 – uroliths of 12–22 mm; 5 – uroliths of 25–35 mm and 6 – a solitary ovoid urolith of 60 × 85 mm.

RESULTS

During the study period – January 2012 to December 2017 – 612 dog uroliths were analyzed in UAL-UAEMex; 41.2% (n = 252) were struvite, 28.3% (n = 173) were calcium oxalate, and the other 30.5% (n = 187) were of other less common minerals such as silicate, purines, cystine and calcium phosphate, in addition to mixed or compound uroliths.

Based on the established selection inclusion and exclusion criteria, a total of 538 cases of dogs with urolithiasis were chosen for this study, of which 224 were SU, 314 OUCG; of the HCG were 896 dogs.

Demographic factors for struvite urolithiasis

Sex. Females with SU were more frequent, with 64.3% (144/224), being significantly over-represented compared to OUCG females ($p<0.001$) and HCG females ($p<0.05$; Table 1).

Breed. SU was identified in 35 pure breeds. The breeds Miniature Schnauzer, Shih Tzu, Yorkshire Terrier, and Pug had the highest odds of developing SU. However, breed association differed according to comparison group (Table 1). The breed identified with lowest odds of developing SU was the Chihuahua ($p<0.001$) in the HCG.

Dog size. Small breeds were more frequently seen in all study groups, and also in the SU group at 83.0% (186/224), and lower in the dogs in the OUCG, at 69.4% (218/314), and 61.2% (548/896) in the HCG. Large-size dogs represented 17% (38/224) of SU cases, 30.6% (96/314) in the OUCG and 38.8% (348/896) in the HGC. In the comparative analysis of SU cases, small-size dogs were at higher chance of developing SU in the HCG ($p <0.001$) and in the OUCG ($p<0.05$) than were large-size dogs (Table 1).

Age. The median age in the SU cases was 7 years (range 1 month to 17 years), higher than in the HCG, which was 5 years (range 6 months to 16 years), but lower than that of the OUCG dogs, at 8 years (range 10 months to 16 years). Dogs 6 to 10 years old had the highest chance of developing SU compared with dogs in the HCG of the same age ($p<0.001$). However, in comparison analysis, SU case aged 6 to 10 years and those older than 10 years had the lowest odds of developing SU ($p<0.05$) compared to OUCG dogs (Table 1).

Table 1. Number, odds ratios and 95% confidence interval for sex, breed and age of dogs with struvite uroliths (n=224) compared to those from the hospital group (n=896) and the group of those with other urolith types (n=314).

Variable	SU cases(n)	HCG (n)	OR (CI95%)	OUCG (n)	OR (CI 95%)
Sex					
Females	144	455	1.7 (1.3–2.4)*	48	9.9 (6.6–15.0)**
Males	80	441	1 (ref)	266	1 (ref)
Breed[a]					
Miniature schnauzer	83	85	5.6 (3.9–7.9)**	86	1.6 (1.1–2.2)*
Poodle	27	126	0.8 (0.5–1.3)	25	1.6 (0.9–2.8)
Labrador Retriever	10	30	1.3 (0.6–2.8)	17	0.8 (0.4–1.8)
Pug	10	30	1.3 (0.6–2.8)	5	2.9 (0.9–8.6)*
Chihuahua	9	131	0.2 (0.1–0.5)**	20	0.6 (0.3–1.4)
Shi Tzu	9	12	3.1 (1.3–7.4) *	7	1.8 (0.7–5.0)
Cocker Spaniel	8	31	1.0 (0.5–2.3)	5	2.3 (0.7–7.1)
Yorkshire Terrier	8	13	2.5 (1.0–6.1) *	15	0.7 (0.3–1.8)
Dog size					
Small size	186	548	3.1 (2.1–4.5)**	218	2.1 (1.4–3.3)*
Large size	38	348	1 (ref)	96	1 (ref)
Age (Years)					
>10	27	87	2.2 (1.3-3.5)*	58	0.4 (0.2-0.7)*
6-10	108	188	4.0 (2.9-5.5)**	173	0.6 (0.4-0.8)*
0-5	89	621	1 (ref)	83	1(ref)

a Breeds shown were the most frequent with SU (n=≥5). When breed was the exposure of interest, each breed was considered, and all other breed served as the reference group for that analysis.
SU cases: cases of struvite urolithiasis; HCG: hospital group; OUCG: dogs with other uroliths types group; ref, reference population. n: number; OR: odds ratios; CI: confidence intervals.
** Highly significant statistical differences (p<0.001). * Statistical significant differences (p<0.05)

Multivariate logistic regression analysis: In multivariate analysis of SU cases compared to HCG, those variables with p < 0.2 were, with respect to sex: females; by breed: Miniature Schnauzer, Yorkshire terrier, Shih tzu and Chihuahua; by size: small-sized dogs; and with respect to age: dogs older than 5 years (Table 2).

In multivariate analysis of SU cases compared to OUCG, the selection of variables with p < 0.2 were, with respect to sex: females; by breed: Miniature Schnauzer, Poodle, Pug, Shih tzu, Cocker Spaniel and Chihuahua; by size: small-sized dogs; and with respect to age: dogs older than 5 years (Table 3).

Table 2. Multivariate logistic regression analysis for factors associated with dogs with struvite urolithiasis compared to dogs in the hospital group.

Variable	OR	CI95%	p
Sex			
Females	1.4	0.9–1.9	0.05*
Breed			
Miniature schnauzer	4.1	2.7–6.1	<0.001**
Shih Tzu	3.3	1.3–8.3	0.01*
Yorkshire Terrier	3.5	1.3–9.3	0.01*
Chihuahua	0.3	0.2-0.7	<0.05*
Dog size			
small size	1.7	1.1–2.6	0.01*
Age			
>5 years	2.9	2.1–4.0	<0.001**

OR: odds ratios; CI: confidence interval; p: statistical significance **Highly significant statistical differences (p<0.001) *Significant statistical differences (p<0.05)

Table 3. Multivariate logistic regression analysis for associated factors of dogs with struvite urolithiasis compared to dogs from the group of those with other urolith types.

Variable	OR	CI95%	p
Sex			
Females	10.0	6.4–15.7	<0.001**
Breed			
Miniature schnauzer	1.3	0.7-2.2	0.4
Poodle	2.0	0.9-4.3	0.08
Pug	2.4	0.6–8.9	0.2
Shih tzu	2.0	0.6-7.1	0.3
Cocker spaniel	2.7	0.7-10.5	0.1
Chihuahua	0.4	0.1-1.2	0.1
Dog size			
Small size	0.9	0.5-1.6	0.6
Age			
>5 years	0.5	0.3-0.8	0.004*

OR: odds ratios; CI: confidence interval; p: statistical significance **Highly significant statistical differences (p<0.001) * Significant statistical differences (p<0.05).

Clinical data of dogs with struvite urolithiasis. Clinical data were obtained from 224 cases of dogs with SU.

Urinary tract location of urolith: 95.1% of the uroliths were in the lower urinary tract – bladder and urethra and 4.9% in the upper urinary tract – kidney and ureters. The frequency and the ORs of the anatomic location of struvite uroliths in relation to sex are given in Table 4.

Urine pH and urine specific gravity: Urinalysis results were reported in only 37.0% (83/224) of SU cases. The median urinary pH value was 7, with a range of 5–9, and mean USG was 1.025 ± 0.009.

Report of previous urolithiasis episodes: previous urolithiasis episodes were reported in only 60 of 162 cases (37.0%), with the recurrence episode occurring any time from the first month to 48 months after urolith extraction. Sixteen dogs (26.7%) had a recurrence within the first year; 34 (56.7%) between the first and second year; and 10 (16.7%) after the third year. There was no significant difference (p > 0.05) between females and males.

Diet: Dogs with SU that consumed commercial diets represented 90.6% (144/159) of cases, while 9.4% (15/159) consumed homemade diets. The diet was not specified in 65 cases.

Table 4. Distribution of the anatomic location, number, and size of struvite uroliths according to sex.

Anatomic location n (%)	Sex n(%)	OR (CI95%)
Bladder 180 (80.4)	F 132 (73.3) M 48 (26.7)	7.3 (3.5–15.4)* 1 (ref)
Urethra 13 (5.8)	F 3 (23.1) M 10(76.9)	0.15 (0.02–0.6) 1 (ref)
Bladder/Urethra 20 (8.9)	F 3 (15) M 17 (85)	0.08 (0.01–0.3) 1 (ref)
Renal 9 (4.0)	F 6 (66.7) M 3 (33.3)	1 (0.2–7.1) 1 (ref)
Ureter 2 (0.9)	F 0 (0) M 2 (100)	ND ND
Number of uroliths n(%) length in mm [minimum-maximum values]		
Solitary urolith 76 (33.9)		
[3-80]	F 58 (76.3)	2.3 (1.2–4.3) *
[3-45]	M 18 (23.7)	1 (ref)
2 -10 uroliths 57 (25.4)		
[1-40]	F 42 (73.7)	2.0 (1.0–3.9)
[2-5]	M 15 (26.3)	1 (ref)
Multiple [a] 64 (28.6)		
[1-62]	F 34 (53.1)	0.5 (0.3–0.9)
[1-20]	M 30 (46.8)	1 (ref)
Sand/ fragments 27 (12.0)		
[1-20]	F 10 (37.0)	0.3 (0.1–0.7)
[1-12]	M 17 (62.9)	1 (ref)

F: females; M: males; ref: reference population; ND: not determined [a] Multiple >10 urolith units per sample; * Significant statistical differences p<0.05.

Physical characteristics and *in vitro* radiographic studies of struvite uroliths. The most frequent physical characteristics of struvite uroliths were round shape (40.2%, 90/224), white color (46.4%, 104/224) and rough surface (57.6%, 129/224). The number of uroliths per dog with SU and their anatomic location within the urinary tract are described in Table 4. Struvite uroliths ranged in size from 1 to 80 mm. In females, uroliths larger than 5 mm were more frequent (71.1%, 159/224).

In vitro radiographic studies revealed that struvite uroliths were of moderate radiopacity (Figure 2). In some uroliths it was possible to distinguish the internal architecture, and the smallest uroliths (Figure 2C 1 and 2).

DISCUSSION

In this study, struvite represented 41.2% of the total samples analyzed in our laboratory, it was the most frequent urolithiasis in dogs, as has been described in other global epidemiological studies carried out in countries such as France and Thailand, with frequencies of 41.9% at 44% (3,7,15). It has been suggested that this high frequency may be associated with the fact that most veterinary clinicians consider the first choice to be the surgical removal of uroliths rather than minimally invasive treatments such as medical dissolution or urohydropropulsion (16,17).

Demographic factors. It was observed that females had higher odds of developing SU than males. One possible cause is that the urethra in females is smaller and wider, allowing upward mobilization of bacteria such as *Staphyloccus spp*. and *Proteus spp*. within the urethra and bladder, causing urinary tract infections and the formation of struvite uroliths (5). Furthermore, it was observed that females with SU were significantly over-represented (OR 10.1; p<0.001) compared to the female/male ratio in the OUCG. These results coincide with that described in other epidemiological studies that report that, among urolith-forming dogs, females have a greater predisposition to SU and males to urolithiasis of calcium oxalate, silicate, cystine and purine (5).

The Yorkshire terrier and Shih Tzu breeds had the highest odds of developing SU when compared to HCG breeds, as did the Pug in the OUCG. The Miniature Schnauzer breed was statistically significant in both comparison groups (OR 5.5; p<0.001 and OR 1.5; p<0.05, respectively). These breeds identified in our study coincide with those reported in other American countries (3,10,13), particularly in a study conducted in California (9). However, there were notable differences with respect to the breeds with the lowest odds of developing SU, i.e., the Chihuahua in Mexico and Australian Cattle Dog, Rottweiler, Boxer and Border Collie in California.

In the OUCG, no breeds were identified as developing SU in the multivariate analysis, possibly because most of the breeds with SU also commonly form other frequently seen urolith types, such as calcium oxalate, in our population of urolith-forming dogs.

The greater probability of developing SU in certain dog breeds is mainly associated with their popularity within dog populations in different geographic areas; however, it has been observed that the size of the dog is a more significant actor in evaluating the possibility of developing urolithiasis (11,13). In our study, the small-size dogs had the highest odds of developing SU, similar to other epidemiological studies (9,11,12). Small-size dogs such as the Miniature Schnauzer have been reported to have a lower urine volume and decreased frequency of urination during the day compared to large dogs such as the Labrador retriever (13), conditions that increase the crystal transit time along the urinary tract, increasing the potential for crystal growth. Another physiological cause could be that the smaller size or narrowness of parts of the urinary tract of these dogs may predispose them to SU (13). It could also be associated with the fact that that in Mexico small-size dogs are popular pets in cities; they accounted for 69% of dogs in the database of our university hospital.

Differences with respect to age in the comparison between the HGC and the OUCG were observed in this study. In the multivariate analysis with HCG, dogs of >5 years of age had the highest chance of developing SU, possibly due to adult dogs presenting different comorbidities such as endocrine, kidney and neurological diseases or other urinary diseases that cause bacterial urinary tract infections such as a secondary alteration, predisposing them to the formation of struvite uroliths (18). However, in the multivariate analysis with the OUCG, dogs of >5 years of age had the lowest odds of developing SU, due mainly to the fact that in our urolith-forming population dogs with SU were younger than those with other urolithiases such as calcium oxalate and silicate (5).

Clinical data. The clinical information of dogs with SU was obtained, and important findings were identified for the diagnosis and follow-up of patients with this pathology.

In dogs with SU, 95.1% of the uroliths were found in the lower urinary tract and 4.9% in the upper urinary tract, which coincides with the anatomic locations previously described by other authors (1,9). Frequent location of uroliths in the lower tract is associated with the horizontal bladder position in dogs, which allows greater storage of of urine in its central area with increased urine volume, so that crystallizable substances tend to precipitate in the ventral wall of the bladder, favoring the retention and growth of crystals to form uroliths. In females it is most common to locate uroliths at this anatomic site, as observed in this study, while in males it was most common to find them simultaneously in the bladder and urethra.

In urinalysis, a median urinary pH of 7 and a mean USG of 1.025±0.009 with a range of 1.002–1.047 were observed. These values coincide with previous findings, where alkaline urine is associated with the presence of urinary tract infections due to urease-positive bacteria (2). Urine with USG values above the critical point (>1.030) may favor crystallization in predisposed animals, and persistent USG values of <1.013 suggest an alteration in one of the defense mechanisms of the urinary tract, favoring bacterial infection (19). In this study, it was not possible to relate SU cases to urinary infection, due to insufficient information on the urine sediment and urine cultures in the urinalysis reports; however, it is considered important to carry out these studies in patients with urolithiasis to identify the microorganism involved and give specific treatment.

Previous episodes of urolithiasis were reported in 37.1% of patients, with the highest percentage of recurrence observed within the first and second years. Possible reasons for recurrence include pseudo-recurrence due to incomplete removal of uroliths by surgical methods, leaving small fragments, or the presence of sutures that act as a nest for the urolith, found in up to 9.4% of cases. Other causes are the incorrect selection or suspension of antimicrobial treatment and a lack of owner compliance in providing a therapeutic diet.

Consumption of commercial diets was frequent in dogs with SU; however, we did not have information on the ingredients in the different commercial diets, and it was not possible to evaluate how this factor would influence the formation of struvite uroliths in dogs. Additional studies should be carried out to identify ingredients, their quality and concentration among the different commercial food brands in Mexico.

In the physical urolith characteristics, we observed that round, white, and rough shapes were the most frequent. According to their size, uroliths of >5 mm were found mainly in females with higher chance of solitary uroliths (OR=2.3); in males, most uroliths were <5 mm, multiple, granular or fragments. The struvite uroliths in this study were the largest compared to uroliths of other minerals, measuring up to 80 mm. These findings coincide with those described by other authors, who observed that struvite uroliths are significantly larger in females than in males, and that uroliths with sizes greater than 20 mm have an 88.7% probability of being composed of struvite, and those of more than 30 mm a 92% probability (7,20).

*In vit*ro radiographic studies showed a moderate degree of radiopacity, and in some cases the different densities between the uroliths allowed identification of their internal layers; these differences may be associated with the structure of these uroliths, which have different textures and porosity types. Theoretically, more porous uroliths may allow antimicrobial penetration or the action dietary factors in urine composition, allowing their dissolution. Therefore, the radiological observation of these characteristics in the structure of the urolith, together with the size, provides guidelines to proceed with non-invasive therapies (2).

In this reference laboratory for urolith analysis located in a Latin American country, in recent years the submission by veterinarians from different regions of Mexico of samples for quantitative analysis has increased, which allowed the identification of struvite as the most frequent urolithiasis, and that the demographic risk factors were females, Miniature Schnauzer, Yorkshire terrier, Shih Tzu, small dogs and age >5 years, reflecting similarities to studies carried out in other reference centes in North America such as Canada or the United States, with the difference that struvite represented the second most frequent urolithiasis and that large breeds are reported to have odds of developing this type of urolithiasis.

Considering the epidemiologic characteristics and clinical data described in this study, such as urine pH≥7, USG≥1.025, radiographic studies with moderately radiopaque uroliths of ≥30 mm and solitary uroliths located in the bladder of females, will help veterinary clinicians to predict that the mineral composition is struvite and hence select less invasive treatments, such as medical dilution or urohydropropulsion, and to recommend prevention strategies for dogs with epidemiologic characteristics suggestive of this type of urolithiasis.

In future studies it will be possible to identify other etiological, environmental, or socioeconomic risk factors that may be involved in SU and other frequent urolithiases in dogs, as complementary information to veterinary clinicians when determining the mineral composition of uroliths before their removal and when selecting specific treatment for each case, in addition to considering the clinical follow-up of these patients because urolithiasis is a multifactorial, chronic, and recurrent disease.

Conflict of interests

The authors of this study declare that there is no conflict of interest with the publication of this manuscript.

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