SMALL ANIMALS

Associations of diet and breed with recurrence of calcium oxalate cystic calculi in dogs

Heidi S. Allen, DVM; William S. Swecker, DVM, PhD; Iveta Becvarova, DVM, MS; Lisa P. Weeth, DVM; Stephen R. Werre, PhD

Objective—To evaluate the long-term risk of recurrence of calcium oxalate (CaOx) cystic calculi in dogs of various breeds fed 1 of 2 therapeutic diets.

Design—Retrospective cohort study.

Animals—135 dogs with a history of CaOx cystic calculi.

Procedures—Medical records for 4 referral hospitals were searched to identify dogs that had had CaOx cystic calculi removed. Owners were contacted and medical records evaluated to obtain information on postoperative diet, recurrence of signs of lower urinary tract disease, and recurrence of cystic calculi. Dogs were grouped on the basis of breed (high-risk breeds, low-risk breeds, and Miniature Schnauzers) and diet fed after removal of cystic calculi (diet A, diet B, and any other diet [diet C], with diets A and B being therapeutic diets formulated to prevent recurrence of CaOx calculi).

Results—Breed group was a significant predictor of calculi recurrence (as determined by abdominal radiography or ultrasonography), with Miniature Schnauzers having 3 times the risk of recurrence as did dogs of other breeds. Dogs in diet group A had a lower prevalence of recurrence than did dogs in diet group C, but this difference was not significant in multivariable analysis.

Conclusions and Clinical Relevance—Results indicated that Miniature Schnauzers had a higher risk of CaOx cystic calculi recurrence than did dogs of other breeds. In addition, findings suggested that diet may play a role in decreasing recurrence, but future prospective studies are needed to validate these observations. (*J Am Vet Med Assoc* 2015;246:1098–1103)

Calcium oxalate calculi are the second most common type of calculi in dogs.[1] Males, small-breed dogs, and middle-aged to older dogs appear to be at an increased risk.[2] In North America, the percentage of canine calculi composed of CaOx has increased from 5.3% in 1989 to 41% in 2007, according to the Minnesota Urolith Center.[1]

The etiology of CaOx cystic calculi in dogs has yet to be determined. Higher urinary concentrations of calcium and oxalate can predispose a dog to develop CaOx calculi, but many other factors play a role, including concentration of urinary CaOx inhibitors, nidus formation, and possibly urine pH. The high prevalence in certain breeds suggests a genetic predisposition to the development of CaOx calculi, and obesity may also be a predisposing factor.[3]

To the authors' knowledge, no studies have evaluated recurrence of CaOx calculi in relationship to breed. Certain breeds appear to have a higher risk of developing CaOx calculi; however, the classification as a high-risk breed differs between studies.[4,5] This may be due to regional differences[6] or the population that is used as a comparison (eg, healthy animals vs those with signs of urinary tract disease). Also, the male-to-female ratio of the hospital population of certain breeds may play a role. In some breeds, such as the Bichon Frise, male dogs are significantly more likely to develop CaOx calculi than are female dogs. Of calculi submitted to the Canadian Veterinary Urolith Center between 1998 and 2008 from male and female Bichon Frise, 89.2% and 17.6% were CaOx, respectively.[7] In contrast, of calculi submitted from male and female Miniature Schnauzers, 89.4% and 47.8%, respectively, were CaOx,[7] and Miniature Schnauzers are reportedly extremely prone to developing CaOx calculi.[8] Although the cause of this predisposition is still being investigated, it may be secondary to increased intestinal absorption or excessive renal excretion of calcium.[9]

The role of diet in urinary excretion of calcium and oxalate and development of CaOx cystic calculi in dogs has been evaluated in several studies. In various studies,[10–12] dogs that produced CaOx cystic calculi had consumed diets that were lower in protein, fat, magnesium, sodium, calcium, phosphorus, potassium, chloride, and moisture and higher in carbohydrates and fiber than had dogs without calculi. A high sodium content in the diet was found to increase

Abbreviation	
CaOx	Calcium oxalate

From the Department of Large Animal Clinical Sciences (Allen, Swecker, Becvarova) and the Laboratory for Study Design and Statistical Analysis (Werre), Virginia-Maryland Regional College of Veterinary Medicine, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061; and the Clinical Nutrition Department, Red Bank Veterinary Hospital, 197 Hance Ave, Tinton Falls, NJ 07724 (Weeth). Dr. Becvarova's present address is Hill's Pet Nutrition Manufacturing, s.r.o. Rohanske nabrezi 678/23, Karlin, Prague 8, 186 00, Czech Republic.
Address correspondence to Dr. Allen (rundvm@gmail.com).

24-hour urinary calcium excretion but also decrease urinary concentration of oxalic acid and CaOx relative supersaturation in dogs.[2,13] Dietary calcium content is positively correlated with urine concentration of calcium and CaOx relative supersaturation.[14]

Calcium oxalate cystic calculi must be removed by means of surgery, urohydropulsion, or lithotripsy because strategies for dissolution have not been developed. The rate of recurrence of CaOx cystic calculi in dogs has been reported to be as high as 90% within 3 years[a] and 100% within 4 years.[15] Two therapeutic diets[b,c] are marketed in the United States specifically to help prevent recurrence of CaOx calculi in dogs. These diets differ in nutrient composition. One has moderate protein and mineral contents, a high sodium content, and an acidic target urine pH.[b] The other has low protein and mineral contents, a moderate magnesium content, and a neutral to alkaline target urine pH.[c] Dogs fed canned diets with characteristics similar to these therapeutic diets in short-term studies (< 3 weeks) had decreased urinary calcium and oxalate concentrations and CaOx relative supersaturation, compared with values when dogs were fed a maintenance diet[16] or their previous diet.[10] To the authors' knowledge, there are no published studies evaluating these 2 therapeutic diets for long-term prevention of CaOx calculi recurrence in dogs.

The purpose of the study reported here was to evaluate the long-term (> 3 months) risk of recurrence of cystic calculi in dogs fed one or the other of these therapeutic diets versus any other diet after removal of CaOx cystic calculi. A secondary objective was to evaluate the association of breed with recurrence of cystic calculi. Our null hypothesis was that the long-term risk of recurrence of CaOx cystic calculi in dogs would not be associated with either breed or diet fed after removal of the calculi.

Materials and Methods

The computerized medical records of 4 referral hospitals (Hope Center for Advanced Veterinary Medicine, Vienna, Virginia; Veterinary Surgical Center, Vienna, Virginia; Virginia-Maryland Regional College of Veterinary Medicine, Blacksburg, Virginia; and Red Bank Veterinary Hospital, Tinton Falls, New Jersey) were searched to identify dogs examined between January 2004 and December 2011 because of cystic calculi. Because classification systems varied among hospitals, a variety of search terms was used, including calculi, calcium oxalate, bladder stone, cystotomy, urohydropulsion, lithotripsy, and cystoscopy. Records were reviewed by one of the authors (HSA) to identify dogs in which cystic calculi had been removed and results of quantitative stone analysis were consistent with CaOx. For dogs with CaOx cystic calculi, medical records were reviewed by the same individual for information on medical history and results of abdominal radiography performed following cystic calculi removal.

Dogs were eligible for inclusion in the study if follow-up records were available for > 1 year after removal of the calculi; the calculi were completely removed by means of surgery, lithotripsy, or urohydropulsion; and the calculi were at least 70% CaOx, as determined by means of quantitative stone analysis. Because results of quantitative analysis were not available for calculi removed from dogs treated at the Veterinary Surgical Center between 2004 and 2005 (3 cases), an assessment by the attending clinician that the calculi were CaOx was considered sufficient for inclusion in the study. Complete removal of calculi was confirmed by means of abdominal radiography performed following calculi removal or, for dogs that underwent surgery, direct examination or palpation, depending on surgeon preference. Dogs with concurrent diseases unlikely to affect long-term survival time, such as hypercalcemia, were included in the analysis, but dogs with concurrent diseases that may have affected long-term survival time were excluded. The Hope Center for Advanced Veterinary Medicine was not found to have any cases that met the inclusion criteria; therefore, only cases from the other 3 referral hospitals were used.

Follow-up information for dogs included in the study was obtained by evaluating medical records and through contact with primary care veterinarians and emergency veterinary clinics. Primary care veterinarians and emergency veterinary clinics were contacted by telephone, followed by a fax and follow-up telephone call if needed. Follow-up information obtained included date and results of any abdominal radiography and abdominal ultrasonography procedures, date of removal and results of analysis of any subsequent calculi, and survival time.

Owners of dogs enrolled in the study were contacted by telephone and asked a predetermined set of questions regarding dietary history and recurrence of signs of lower urinary tract disease after surgery.[d] The dietary history included specific information on diet as well as information on treats and other foods given. Recurrence was defined as development of at least 1 of the following signs > 2 weeks after initial calculi removal: hematuria, pollakiuria, stranguria, painful urination, or inability to urinate. If information about diet and recurrence of signs of lower urinary tract disease could not be obtained from the owner, the medical records were evaluated. Participating referral hospitals provided permission for the investigators to communicate with referring veterinarians and owners of dogs included in the study.

Two endpoints were defined. The imaging endpoint was defined as the date following initial calculi removal that cystic calculus recurrence was diagnosed by means of abdominal radiography or ultrasonography (imaging recurrence) or the last date that abdominal radiography or ultrasonography was performed in dogs without cystic calculus recurrence (no imaging recurrence). Abdominal radiography or ultrasonography may have been performed because of recurrence of clinical signs, for purposes of routine monitoring, or because of development of a new problem.

The clinical endpoint was defined as the date following initial calculi removal that clinical signs of urinary tract disease recurred (clinical recurrence) or, for dogs in which clinical signs of urinary tract disease did not recur, the date of last communication with the client, the date of last examination by a veterinarian, or the date of death. Only imaging and clinical endpoints that occurred ≥ 3 months after initial calculi removal were included in statistical analyses, and dogs were excluded from the study if they did not have at least 1 endpoint ≥ 3 months after initial calculi removal. For dogs fed a therapeutic diet formulated to prevent recurrence following initial calculi removal that underwent a diet change, the date of the diet change was recorded, and only information obtained prior to the diet change was used in the statistical analyses.

Dogs were classified into 3 diet groups (A, B, and C) on the basis of diet fed following initial calculi removal. Diet group A consisted of dogs fed a therapeutic diet[b] (canned, dry, or a combination) with moderate protein, calcium, phosphorus, and magnesium contents; high sodium content; and target urine pH of 5.5 to 6.0 (**Appendix**). Diet group B consisted of dogs fed a therapeutic diet[c] (canned, dry, or a combination) with low protein, calcium, phosphorus, and sodium contents; a moderate magnesium content; and a target urine pH of 7.1 to 7.7. Diet group C consisted of dogs fed any other diet, whether a commercial diet, home-cooked diet, or other therapeutic diet. Because most of the dogs fed 1 of the 2 therapeutic diets were also fed treats or other foods, dogs were included in diet group A or B so long as treats, other diets, human foods, or other foods did not make up > 10% of daily caloric intake. Dogs fed 1 of the 2 therapeutic diets that were also fed other diets, human foods, treats, or other foods that made up > 10% of daily caloric intake were classified in diet group C.

Dogs were also classified into 3 breed groups (high-risk breed group, low-risk breed group, and Miniature Schnauzers) on the basis of previously reported breed risk for CaOx calculi formation. Dogs in the high-risk breed group consisted of Bichon Frise, Cairn Terriers, Jack Russell Terriers, Keeshonden, Lhasa Apsos, Maltese, Papillions, Pomeranians, Shih Tzus, and Yorkshire Terriers (ie, breeds with an OR ≥ 5.0 in previous studies[4,5]). Dogs in the low-risk breed group consisted of all dogs other than Miniature Schnauzers and those in the high-risk breed group. Miniature Schnauzers were assigned to a separate group because of the high prevalence of CaOx calculi in this breed.[8]

Statistical analysis—For purposes of statistical analyses, age was defined as age of the dog at the time of initial cystic calculi removal and hospital was defined as the referral hospital where the removal procedure was performed. Main outcomes of interest were prevalence of imaging recurrence, prevalence of clinical recurrence, time to imaging recurrence, and time to clinical recurrence. The primary exposure of interest was diet group; the secondary exposure of interest was breed group. Potential prognostic factors examined for an association with recurrence of cystic calculi included sex, previous history of calculi, age, hospital, and whether radiographs were obtained following calculi removal. Bivariable associations between each of the potential prognostic factors and each of the 2 exposures of interest (diet group and breed group) were tested by means of ANOVA (age) and χ^2 tests (sex, previous history of calculi, hospital, and radiographs obtained following calculi removal). Associations between each of the potential prognostic factors and recurrence (imaging or clinical) were tested by use of a 2-sample *t* test (age) and χ^2 tests (diet, breed, sex, previous history of calculi, hospital, and radiographs obtained following calculi removal). Associations between each of the potential prognostic factors and time to recurrence were tested by means of linear regression (age) and log-rank tests (diet, breed, sex, previous history of calculi, hospital, and radiographs obtained following calculi removal). Subsequently, the effects of diet and breed on prevalence of recurrence (imaging or clinical) after adjusting for potential confounders were assessed by means of multivariable logistic regression, and the effects of diet

Table 1—Characteristics of 135 dogs grouped on the basis of CaOx formation risk that underwent CaOx cystic calculi removal between January 2004 and December 2011.

Variable	Low-risk breeds	High-risk breeds	Miniature Schnauzers	*P* value
Sex				0.40
Male	37 (70)	42 (78)	18 (64)	
Female	16 (30)	12 (22)	10 (36)	
Previous history of calculi	10 (19)	14 (26)	10 (36)	0.25
Hospital*				0.008
1	8 (15)	14 (26)	4 (14)	
2	17 (32)	12 (22)	17 (61)	
3	28 (53)	28 (52)	7 (25)	
Radiographs†	31 (58)	28 (52)	24 (86)	0.01
Diet				0.71
A	14 (26)	13 (24)	5 (18)	
B	4 (8)	8 (15)	3 (11)	
C	35 (66)	33 (61)	20 (71)	
Mean ± SD age (y)‡	8.1 ± 2.9	7.7 ± 2.6	8.6 ± 1.9	0.37

Results are given as number (%) of dogs, except for age. Dogs were grouped into 3 breed groups on the basis of previously reported[4,5,8] breed risk for CaOx calculi formation (low-risk breeds [all breeds other than Miniature Schnauzer and breeds in the high-risk breed group; n = 53], high-risk breeds [Bichon Frise, Cairn Terrier, Jack Russell Terrier, Keeshond, Lhasa Apso, Maltese, Papillion, Pomeranian, Shih Tzu, and Yorkshire Terrier; 54], and Miniature Schnauzers [28]). Dogs in diet groups A and B were fed 1 of 2 therapeutic diets formulated to prevent recurrence of CaOx calculi following CaOx cystic calculi removal; dogs in diet group C were fed any other diet.

*Cystic calculi were removed at 1 of 3 referral veterinary hospitals. †Abdominal radiographs were obtained following cystic calculi removal. ‡Age at the time of calculi removal.

and breed on median time to recurrence after adjusting for potential confounders were assessed by means of multivariable Cox regression. Where appropriate, *P* values were adjusted for multiple comparisons by means of the Bonferroni procedure. All statistical analyses were performed with standard software.[17,e] Values of $P < 0.05$ were considered significant.

Results

A total of 135 dogs representing 38 breeds met the inclusion criteria. Mean ± SD age at initial calculi removal was 8.0 ± 2.6 years. Thirty-eight dogs were female (36 spayed and 2 sexually intact) and 97 were male (89 neutered and 8 sexually intact). Fifty-four dogs were classified in the high-risk breed group, and 53 were classified in the low-risk breed group. The remaining 28 dogs were Miniature Schnauzers. There were no significant differences among breed groups with respect to age at the time of initial calculi removal, sex, diet, or previous history of calculi. Miniature Schnauzers were significantly overrepresented at the Virginia-Maryland Regional College of Veterinary Medicine, compared with dogs in the high-risk and low-risk breed groups. The percentage of Miniature Schnauzers that had radiographs obtained after initial calculi removal was significantly higher than the percentages of dogs in the other groups that did **(Table 1)**.

Of the 135 dogs, 32 were classified in diet group A, 15 were classified in diet group B, and 88 were classified in diet group C. There were no significant differences among diet groups with respect to age at time of initial calculi removal, sex, breed, previous history of calculi, hospital, or radiographs obtained following calculi removal **(Table 2)**.

Information on clinical endpoint (ie, recurrence of signs of urinary tract disease) was available for 133 of the 135 dogs. Signs of urinary tract disease recurred in 39 of the 133 dogs. There was no significant effect of diet group ($P = 0.38$), breed group ($P = 0.18$), or other variables on prevalence of clinical recurrence. Diet group (log-rank test; $P = 0.31$), breed group (log-rank test; $P = 0.16$), and other variables tested also were not significantly associated with median time to clinical recurrence.

Information on imaging endpoint (ie, cystic calculus recurrence identified by means of abdominal radiography or ultrasonography) was available for 82 of the 135 dogs. Cystic calculi were detected by means of abdominal radiography or ultrasonography in 41 of the 82. Of the 41 dogs with recurrence, 20 underwent calculi removal, and calculi from 18 of the 20 dogs were submitted for analysis. Seventeen dogs had CaOx calculi, and 1 had a magnesium ammonium phosphate calculus.

Dogs in diet group A had a significantly ($P = 0.03$) lower prevalence of imaging recurrence than did dogs in diet group C **(Table 3)**. However, prevalence of imaging recurrence was not significantly different between diet group A and diet group B ($P = 1.0$) or between diet group B and diet group C ($P = 1.0$). Breed group was not significantly ($P = 0.27$) associated with prevalence of imaging recurrence.

Breed group ($P = 0.02$), but not diet group ($P = 0.052$), was found by means of multivariable logistic regression to be significantly associated with time to imaging recurrence **(Figures 1 and 2)**. Specifically, after adjusting for diet, both the high-risk breed group (hazard ratio, 0.3; 95% confidence interval, 0.1 to 0.7; $P = 0.01$) and low-risk breed group (hazard ratio, 0.4; 95% confidence interval, 0.2 to 0.9; $P = 0.03$) had a third the risk of developing an imaging recurrence as did Miniature Schnauzers. Multivariable regression did not identify any factors significantly associated with prevalence of imaging recurrence, prevalence of clinical recurrence, or median time to clinical recurrence.

Table 2—Characteristics of the same dogs as in Table 1, grouped according to diet fed following CaOx cystic calculi removal.

	Diet group			
Variable	A	B	C	*P* value
Sex				0.23
Male	23 (72)	8 (53)	66 (75)	
Female	9 (28)	7 (47)	22 (25)	
Breed group				0.71
High-risk	13 (41)	8 (53)	33 (37)	
Low-risk	14 (44)	4 (27)	35 (40)	
Miniature Schnauzers	5 (16)	3 (20)	20 (23)	
Previous history of calculi	7 (22)	4 (27)	23 (26)	0.88
Hospital*				0.46
1	8 (25)	4 (27)	14 (16)	
2	12 (38)	6 (40)	28 (32)	
3	12 (38)	5 (33)	46 (52)	
Radiographs†	23 (72)	8 (53)	52 (59)	0.35
Mean ± SD age (y)‡	8.1 ± 2.5	7.0 ± 1.7	8.0 ± 2.7	0.48

Results are given as number (%) of dogs, except for age. Dogs in diet groups A (n = 32) and B (15) were fed 1 of 2 therapeutic diets formulated to prevent recurrence of CaOx calculi following CaOx cystic calculi removal; dogs in diet group C (88) were fed any other diet.
See Table 1 for remainder of key.

Table 3—Prevalence of cystic calculi recurrence and time to recurrence (as determined by means of abdominal radiography or ultrasonography) for 82 dogs that underwent CaOx cystic calculi removal.

	Diet group			Breed group		
Variable	A	B	C	Low-risk	High-risk	Miniature Schnauzers
Dogs with recurrence*	4/17 (24)[a]	5/11 (45)[a,b]	32/54 (59)[b]	10/26 (38)[a]	18/35 (51)[a]	13/21 (62)[a]
Median time (y) to recurrence (95% CI)	5.6[a] (2.5–5.6)	1.8[a] (ND)	2.1[a] (1.8–3.1)	3.6[a] (1.7–5.6)	3.1[a] (2.1–3.7)	1.8[b] (1.2–2.8)

*Data are given as number of dogs with recurrence/number of dogs in group (%).
CI = Confidence interval. ND = Not determined (owing to the low number of dogs).
[a,b]Within each row and group (diet or breed), values with different superscript letters were significantly ($P < 0.05$) different.
See Tables 1 and 2 for remainder of key.

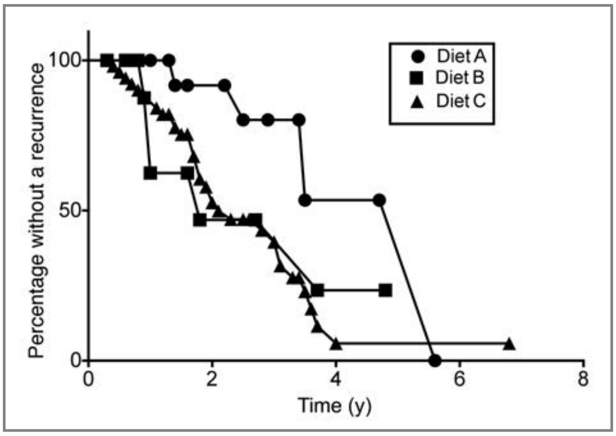

Figure 1—Kaplan-Meier curves of time to calculi recurrence (as determined by means of abdominal radiography or ultrasonography) among dogs fed 1 of 2 therapeutic diets formulated to prevent recurrence of CaOx calculi (diet groups A [n = 17] and B [11]) or any other diet (diet group C [54]) following initial CaOx cystic calculi removal.

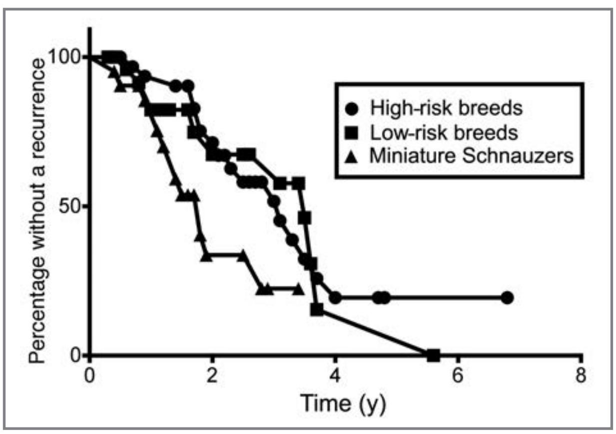

Figure 2—Kaplan-Meier curves of time to calculi recurrence (as determined by means of abdominal radiography or ultrasonography) following initial CaOx cystic calculi removal among 82 dogs grouped on the basis of breed (high-risk breeds [Bichon Frise, Cairn Terrier, Jack Russell Terrier, Keeshond, Lhasa Apso, Maltese, Papillion, Pomeranian, Shih Tzu, and Yorkshire Terrier; n = 35], low-risk breeds [all breeds other than Miniature Schnauzer and breeds in the high-risk breed group; 26], and Miniature Schnauzers [21]).

Discussion

In the present study, breed group was significantly associated with time to imaging recurrence of CaOx cystic calculi, with both the high-risk and low-risk breed groups having one-third the risk of developing an imaging recurrence as did Miniature Schnauzers. Diet group was significantly associated with prevalence of imaging recurrence in χ^2 analysis but not in multivariable analysis. Because this was a retrospective study, the authors had no control over the distribution of cases into the various diet groups or follow-up management of the dogs. The low number of dogs in some groups should be considered when interpreting our results.

In the present study, Miniature Schnauzers were significantly overrepresented at the Virginia-Maryland Regional College of Veterinary Medicine, compared with dogs in the high-risk and low-risk breed groups. This may have been due to the fact that this specialty hospital is a tertiary-care facility that has the capability to perform lithotripsy. Because Miniature Schnauzers have a high predisposition for CaOx calculi, many owners may elect noninvasive treatment, such as lithotripsy, even the first time the dog undergoes calculi removal. Miniature Schnauzers also had radiographs taken after initial removal of the calculi more frequently than did dogs in the high-risk and low-risk breed groups. The reason for this was not known. The Virginia-Maryland Regional College of Veterinary Medicine had a high percentage of dogs in which radiographs were obtained after calculi removal (87%), which may have accounted for the high percentage of Miniature Schnauzers that had radiographs obtained (85.7%). Neither hospital nor whether radiographs were obtained after calculi removal was significantly associated with prevalence of imaging recurrence. Prospective studies with a larger population of Miniature Schnauzers fed diets similar to those fed to dogs of other breeds should be performed to further evaluate the prevalence of recurrence in this breed.

Of the 82 dogs for which information on imaging endpoint was available, 41 had evidence of cystic calculi recurrence. However, only 20 of these dogs had the calculi removed. Because CaOx calculi frequently recur and often do not cause clinical signs, owners and veterinarians may elect to not remove recurrent cystic calculi. The dog that developed a magnesium ammonium phosphate calculus during the follow-up period was a spayed female Shih Tzu in diet group B. Unfortunately, there were no records of a urinalysis or urine culture performed at that time.

Despite the availability of therapeutic diets designed to help prevent recurrence of CaOx calculi, most (88/135 [65.2%]) dogs in the present study were fed other diets (diet group C). Unfortunately, it was not known whether the diets fed to dogs in diet group C were diets recommended by a veterinarian following the diagnosis of CaOx cystic calculi or diets chosen by the owners. Not unexpectedly, a high percentage of owners gave treats no matter what diet they fed to their pets. Providing specific treat options for owners could be important in preventing CaOx calculi recurrence, considering that some treats may be high in calcium and oxalate precursors.

Dogs in diet group C in the present study were fed a variety of diets and not a control diet with a fixed nutrient profile. Dogs in diet groups A and B were not further separated into categories on the basis of diet type (ie, dry vs canned) because this would have decreased the number of dogs in each group, minimizing the power of the study. As with all unblinded, retrospective studies, bias in data collection was a concern. The study relied on the owners' recollection of dietary histories and on medical records, which had differing formats and may not have been complete. All of these factors are common in these types of retrospective studies and should be considered when interpreting our results. Well-designed prospective studies are needed to evaluate the long-term effect of various therapeutic diets, compared with a consistent control diet, for preventing recurrence of CaOx calculi in dogs.

In conclusion, in the present study, we found that Miniature Schnauzers that had undergone CaOx calculi

SMALL ANIMALS

removal had a significantly shorter time to recurrence of calculi, compared with dogs of other breeds. In addition, findings suggested that diet may play a role in decreasing recurrence, but this was found only in univariate analyses, not in multivariable analysis.

a. Lulich JP, Perrine L, Osborne CA, et al. Postsurgical recurrence of calcium oxalate uroliths in dogs (abstr). *J Vet Intern Med* 1992;6:119.
b. Royal Canin Canine Urinary SO, Royal Canin, St Charles, Mo.
c. Prescription Diet u/d, Canine Non-struvite Urinary Tract Health, Hill's Pet Nutrition Inc, Topeka, Kan.
d. Copies of the questionnaire are available from the corresponding author on request.
e. SAS, version 9.3, SAS Institute Inc, Cary, NC.

References

1. Osborne CA, Lulich JP, Kruger JM, et al. 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* 2009;39:183–197.
2. Lulich JP, Osborne CA, Thumchai R, et al. Epidemiology of canine calcium oxalate uroliths. *Vet Clin North Am Small Anim Pract* 1999;29:113–122.
3. Wisener LV, Pearl DL, Houston DM, et al. Risk factors for the incidence of calcium oxalate uroliths or magnesium ammonium phosphate uroliths for dogs in Ontario, Canada, from 1998 to 2006. *Am J Vet Res* 2010;71:1045–1054.
4. Low WW, Uhl JM, Kass PH, et al. Evaluation of trends in urolith composition and characteristics of dogs with urolithiasis: 25,499 cases (1985–2006). *J Am Vet Med Assoc* 2010;236:193–200.
5. Lekcharoensuk C, Lulich JP, Osborne CA, et al. Patient and environmental factors associated with calcium oxalate urolithiasis in dogs. *J Am Vet Med Assoc* 2000;217:515–519.
6. Franti CE, Ling GV, Ruby AL, et al. Urolithiasis in dogs V: regional comparisons of breed, age, sex, anatomic location, and mineral type of calculus. *Am J Vet Res* 1999;60:29–42.
7. Houston DM, Moore AEP. Canine and feline urolithiasis: examination of over 50,000 urolith submissions to the Canadian Veterinary Urolith Centre from 1998–2008. *Can Vet J* 2009;50:1263–1268.
8. Lulich JP, Osborne CA, Unger LK, et al. Prevalence of calcium oxalate uroliths in Miniature Schnauzers. *Am J Vet Res* 1991;52:1579–1582.
9. Lulich JP, Osborne CA, Nagode LA, et al. Evaluation of urine and serum metabolites in Miniature Schnauzers with calcium oxalate uroliths. *Am J Vet Res* 1991;52:1583–1590.
10. Stevenson AE, Blackburn JM, Markwell PJ, et al. Nutrient intake and urine composition in calcium oxalate stone-forming dogs: comparison with healthy dogs and impact of dietary modification. *Vet Ther* 2004;5:218–231.
11. Lekcharoensuk C, Osborne CA, Lulich JP, et al. Association between dietary factors in canned food and formation of calcium oxalate uroliths in dogs. *Am J Vet Res* 2002;63:163–169.
12. Lekcharoensuk C, Osborne CA, Lulich JP, et al. Association between dry dietary factors and canine calcium oxalate uroliths. *Am J Vet Res* 2002;63:330–337.
13. Lulich JP, Osborne CA, Sanderson SL. Effects of dietary supplementation with sodium chloride on urinary relative supersaturation with calcium oxalate in healthy dogs. *Am J Vet Res* 2005;66:319–324.
14. Stevenson AE, Hynds WK, Markwell PJ. The relative effects of supplemental dietary calcium and oxalate on urine composition and calcium oxalate relative supersaturation in healthy adult dogs. *Res Vet Sci* 2003;75:33–41.
15. Lulich JP, Osborne CA, Daubs TH. Biologic behavior of calcium oxalate uroliths in Bichon Frise dogs. *J Vet Intern Med* 2004;18:440–441.
16. Lulich JP, Osborne CA, Lekcharoensuk C, et al. Effects of hydrochlorothiazide and diet in dogs with calcium oxalate urolithiasis. *J Am Vet Med Assoc* 2001;218:1583–1586.
17. *SAS/STAT 9.3 user's guide*. Cary, NC: SAS Institute Inc, 2011.

Appendix

Nutrient composition and target urine pH of 2 therapeutic diets formulated to prevent recurrence of CaOx cystic calculi in dogs.

Variable	Diet A[b]		Diet B[c]	
	Dry	Canned	Dry	Canned
Caloric energy on an as-fed basis (kcal/kg)	3,894	1,226	4,015	1,322
Moisture (%)	10	75	7	71
Protein (g/1,000 kcal)	41	45	25	29
Fat (g/1,000 kcal)	41	60	48	58
Sodium (g/1,000 kcal)	3.2	2	0.8	0.6
Calcium (g/1,000 kcal)	1.8	2	0.8	0.8
Phosphorus (g/1,000 kcal)	1.5	1.9	0.5	0.4
Magnesium (g/1,000 kcal)	0.2	0.1	0.1	0.1
Target urine pH	5.5–6.0	5.5–6.0	7.1–7.7	7.1–7.7

Data represent results of a typical analysis per manufacturer's information.