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Effect of a struvite dissolution diet in cats with naturally occurring struvite urolithiasis

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Abstract

Objectives The aim of the study was to determine the efficacy of the low struvite relative supersaturation diet in dissolution of feline struvite cystoliths.
Methods This was a prospective, open-label, two-center study. Twelve client-owned cats were enrolled based on the radiographic appearance of their uroliths and urinalysis parameters. Cats were fed the test diet exclusively for up to 56 days. Cats were radiographed every other week until radiographic evidence of dissolution occurred or the end of the study period was reached. Cats with radiographically apparent uroliths at the end of the study period underwent cystotomy for stone retrieval and analysis.
Results Nine of the 12 cats completed the study. Eight experienced radiographic dissolution; seven of these had complete dissolution within the first month of treatment. One cat, whose owner declined cystotomy after partial dissolution at day 56, had complete radiographic resolution at 70 days of treatment. Two calcium oxalate urolith cores were removed from a cat that had partial radiographic dissolution.
Conclusions and relevance The test diet was successful in dissolving suspected struvite cystoliths. As this diet is suitable for maintenance feeding of adult cats, it may be a suitable choice for long-term prevention of feline struvite urolithiasis.

Keywords: Bladder stones; cystolith; magnesium ammonium phosphate; sterile struvite; nutritional management

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Introduction

Urolithiasis is responsible for 10–23% of lower urinary tract signs in cats.[1–3] Approximately half the feline uroliths submitted to North American analysis centers are composed primarily of struvite.[4–6] Although this proportion is lower than 30 years ago, when nearly 80% were struvite, they still present a significant cause of urolithiasis. The precipitation of struvite into uroliths depends on many factors including the degree of urine saturation, the presence or lack of promoters and inhibitors of precipitation, diet, pH of the urine and volume of the urine.[6] In cats, unlike in dogs, struvite uroliths are usually formed in sterile urine, and are not associated with urease-producing bacteria.[7]

Dietary formulation for struvite urolith dissolution was first described in 1983.[8] It has now become the standard of care for treatment of both sterile and infection-induced struvite uroliths.[9] Dietary recommendations for treatment of struvite uroliths include increasing water intake, restricting phosphorus and magnesium content, and moderate urinary acidification.[10]

In a premarketing study of 10 clinically normal adult cats (2–14 years old), the commercially available diet studied herein (Blue Natural Veterinary Diet W+U Weight Management+Urinary Care; Blue Buffalo Company) was fed exclusively for 23 days prior to urine collection

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for urinary relative supersaturation (RSS) measurement. The test diet maintained a 24 h RSS level less than 1 for struvite and maintained a mean urine pH of 6.0[11] (Blue Buffalo Company, data on file, 2016). Both of these qualities are predicted to prevent and dissolve struvite cystoliths.[12,13] The RSS is based on concentrations of crystal components, as well as pH, of urine collected from animals fed the tested diet, and has been used to describe the efficacy of diet in managing urolithiasis in cats.[14]

The primary objectives of this study were to determine the efficacy and speed of the test diet in dissolution of naturally occurring feline struvite uroliths. We hypothesized that exclusive feeding of the test diet would lead to complete radiographic dissolution in less than 56 days. In addition, the influence of the test diet on blood and urine parameters was also evaluated.

Materials and methods

Animals

Client-owned, adult cats of either sex and any breed were recruited for the study between December 2017 and June 2019 if their veterinarian suspected struvite urolithiasis. All cats were screened at one of two academic teaching hospitals prior to enrollment (The Ohio State University Veterinary Medical Center, Columbus, OH and North Carolina State University Veterinary Hospital, Raleigh, NC). This study was approved by the Institutional Animal Care and Use Committees at The Ohio State University and the North Carolina State University. Informed owner consent was obtained before screening.

Screening consisted of a physical examination, body condition scoring on a nine-point scale, body weight, complete blood count (CBC), serum biochemistry panel, urinalysis with pH determined by reagent test strip, aerobic urine culture and three view abdominal radiographs. Cats were enrolled in the study on the basis of radiographic appearance of uroliths (ie, moderately opaque, round or discoid cystoliths) and urinalysis parameters (ie, pH $\geqslant$6.5). Clinical signs of lower urinary tract disease did not need to be present for consideration for enrollment. Cats were excluded if there was evidence of nephrolithiasis, ureterolithiasis or hypercalcemia, as these may indicate the uroliths were less likely to be struvite in composition. Other exclusions included urinary tract obstruction, systemic disease (eg, hyperthyroidism, diabetes mellitus, renal disease, liver disease, hypercalcemia, anemia) or treatment with urinary acidifiers, corticosteroids, diuretics or having been fed a diet formulated to dissolve struvite uroliths in the previous 3 weeks. Antibiotic use was not considered an exclusionary criterion.

Study protocol

Cats enrolled in the study were required to be exclusively fed the test diet – a commercially produced dry cat food (see supplementary material 1 and 2). Animal feeding tests using the protocol of the Association of American Feed Control Officials (AAFCO) demonstrated that the test diet met the nutritional requirements for maintenance feeding of adult cats. No other foods, including supplements, vitamins or treats, were permitted. Owners were instructed to have fresh water available at all times. The maintenance energy requirement for each cat was calculated based on the formula 1.2*(70*[weight in kg$^{0.75}$]). The daily amount of food to offer each cat was based on this calculation. Feeding of the test diet was to begin either immediately after screening or after a 1-week transitionary period. The decision on which method to use to introduce the test diet was up to clinician and owner preference. Cats were required to be housed indoors for the duration of the study to help eliminate deviation from the test diet. In multi-cat households, enough test diet was dispensed to feed all cats in the household.

The owners maintained daily logs of the amount of test diet offered each day, the amount of test diet eaten, any food items offered other than the test diet, activity levels of the cat, and incidence of vomiting or diarrhea. The logs were monitored at each re-evaluation. The academic teaching hospital that had enrolled the cat performed re-evaluations at 2-week intervals after the cat had been exclusively eating the test diet. Physical examination, body condition scoring, body weight, urinalysis and three view abdominal radiographs were performed at each re-evaluation. The daily amount of food to offer the cat was recalculated based on contemporaneous body weight at each visit.

All radiographs were reviewed by a single board-certified veterinary radiologist (ETH) to measure urolith size and assess the degree of dissolution at each time point. If stones were no longer radiographically evident, a CBC, serum biochemistry and aerobic urine culture were performed. Clients whose cats had successfully undergone urolith dissolution were provided with the test diet in a quantity sufficient to feed all cats in the household for an additional 6 months. Owners were telephoned at the end of this 6-month period to inquire about recurrence of lower urinary tract signs in their cat. Cats that did not have complete stone dissolution by day 56 of exclusively consuming the test diet were to have a cystotomy performed so that uroliths could be retrieved and analyzed at a veterinary laboratory performing quantitative mineral analysis (Gerald V Ling Urinary Stone Analysis Laboratory, University of California, Davis, CA).

Owners were permitted to withdraw their cat from the study at any time, for any reason. Cats were withdrawn from the study by the investigators if they failed to consume an adequate amount of the test diet for maintenance of weight, were fed food other than the test diet, displayed intolerance of the diet, developed urinary obstruction or developed other systemic illness.

Statistical methods

Statistical analysis was performed using commercially available software (GraphPad Prism 8 for macOS, GraphPad Software). Descriptive statistics were calculated for all cats. A two-tailed, paired *t*-test was used to compare CBC, biochemical and urinalysis parameters at the time of screening and at the time of complete stone dissolution. Statistical significance was set at $P < 0.05$.

Results

Twelve cats were enrolled in the study out of 19 cats screened for inclusion. Of the seven cats excluded, three were disqualified for lack of radiopaque uroliths on radiographs, one for bilateral nephrolithiasis, one for urethrolithiasis, one for lack of a urinalysis and culture, and one for a urine pH of 6.0. Of the enrolled cats, there were 11 domestic shorthairs and one domestic longhair. There were seven spayed females, one intact female and four castrated male cats. The median age of the cats was 5 years (range: 1–8 years). The median weight of the cats was 6.15 kg (range: 3.4–9 kg). Ten of the enrolled cats were considered to be overweight or obese based on body condition score (BCS). One cat had a BCS of 4, one cat had a BCS of 5, one cat had a BCS of 6, two had a BCS of 7, three had a BCS of 8 and four had a BCS of 9. Clinical signs of lower urinary tract disease (number of cats, %) reported at the time of enrollment included hematuria (11, 92%), periuria (6, 50%) and stranguria (3, 25%). Every cat had at least one clinical sign reported; some cats had more than one clinical sign reported.

Nine of the 12 (75%) enrolled cats completed the study (Table 1). Of the three cats that were withdrawn, one was fed food other than the test diet, one female developed urethral obstruction from what was determined to be a struvite urolith and one developed an incompletely diagnosed systemic illness involving hyporexia weight loss and hyponatremia. The data from these cats were excluded from further analysis. No other adverse events were noted during the study.

Seven of the nine (78%) cats completing the study experienced complete radiographic resolution of their cystic calculi by day 56. Two cats (22%) had radiographic resolution at day 14, and five cats (56%) had radiographic resolution at day 28. Two cats had partial radiographic dissolution of their cystic calculi at day 56. One cat (11%) had partial radiographic resolution at day 56, at which time the cystoliths appeared sand-like. The owner declined cystotomy and continued to feed the diet as prescribed. This cat had complete radiographic resolution at a recheck on day 70 after starting the diet. One additional cat (11%) did not experience complete radiographic resolution by day 56. The initial radiographs revealed a core of increased mineral opacity within each of the two cystoliths (Figure 1a). The calculi had significantly reduced in size on the day 14 and day 28 radiographs, but then remained static in size on radiographs on days 42 and 56 (Figure 1b). A cystotomy was performed and two calculi were removed, which were determined to be 100% calcium oxalate with small struvite deposits on the surface at analysis. The data from this cat were excluded from further analysis.

For the seven cats that experienced complete stone dissolution within 56 days, there was no significant difference in CBC or biochemical parameters at screening or after complete stone dissolution. The screening urinalyses in the seven cats revealed a median urine specific gravity (USG) of 1.047 (range: 1.039–1.051) and median pH of 7.0 (range: 6.5–9.0). One cat had crystalluria with 1–5 calcium oxalate crystals/high-power field (hpf) and 6–20 struvite crystals/hpf; no cats had cylindruria. All cats had microscopic hematuria and five had macroscopic hematuria. One cat had a positive urine culture growing 10,000–50,000 colony-forming units/ml of hemolytic *Escherichia coli*; the remaining urine cultures had no aerobic growth. A decision was made not to treat the bacteriuria in the cat with a positive urine culture because it had no pyuria and the straining was thought to be due to the cystoliths. This cat experienced complete stone dissolution by day 28.

At the time of complete stone dissolution, the urinalyses of the seven cats that had complete dissolution within 56 days revealed a median USG of 1.051 (range: 1.035–1.065) and median pH of 6.0 (range: 6.0–6.5). The USG was not statistically different in comparison with the value at screening ($P = 0.095$); however, the pH was significantly lower in comparison with the values at screening ($P = 0.009$) (Figure 2). No cats had crystalluria or cylindruria. Four cats had microscopic hematuria and none had macroscopic hematuria. No cats had aerobic growth on urine culture.

At the time of screening, the urinalysis of the cat that experienced a prolonged time to stone dissolution revealed a USG of 1.020 and a pH of 6.5. There was no crystalluria or cylindruria. Macroscopic hematuria was present and radiographs revealed a very large stone burden (Figure 3). The urine culture had no aerobic growth. At the time of stone dissolution on day 70, the urinalysis revealed a USG of 1.050 and a pH of 6.0. There was no crystalluria or cylindruria. No hematuria was present, microscopically or macroscopically. The urine culture had no aerobic growth.

At the time of screening, the urinalysis of the other cat that did not experience complete stone dissolution revealed a USG of 1.047 and a pH of 7.5. Struvite crystalluria was present. There was no cylindruria. Microscopic, but not macroscopic, hematuria was present. The urine culture had no aerobic growth. At the time of cystotomy, the urinalysis revealed a USG of 1.045 and a pH of 6. There was no crystalluria or cylindruria. No hematuria was present, microscopically or macroscopically. The urine culture had no aerobic growth.

Table 1 Summary of case information from cats with diet-induced struvite urolith dissolution

									Screening			Dissolution			
Cat	Age (years)	Sex	Breed	Body weight (kg)	BCS (1–9)	Hematuria	Periuria	Stranguria	Radiographs	Urine pH	USG	Time (days)	Urine pH	USG	Response
1	5	FS	DSH	4.3	5	+	–	+	One round cystic calculus, measuring 6.29 mm in diameter	7	1.050	28	6	1.050	Complete
2	3	FS	DSH	3.4	4	+	–	–	One discoid cystic calculus, measuring 9.19 mm × 1.87 mm	9	1.048	14	6	1.050	Complete
3	1	FS	DSH	5.5	7	+	+	–	Eight ovoid cystic calculi, the largest measuring 4.43 mm × 2.62 mm	8	1.040	28	6	1.035	Complete
4	2	FI	DSH	7.9	9	+	–	–	At least 21 round cystic calculi, the largest measuring 5.16 mm in diameter	6.5	1.020	70	6	1.050	Partial
5	2	MC	DSH	5.5	8	+	+	+	Three ovoid cystic calculi, the largest measuring 6.34 mm × 3.62 mm	7	1.043	28	6	1.062	Complete
6	5	FS	DSH	6.8	8	+	–	+	Seven round cystic calculi, the largest 4.11 mm in diameter	6.5	1.051	28	6	1.065	Complete
7	8	MC	DSH	8.5	9	–	+	–	Two moderately radiopaque stones, with more opaque center, largest measuring 7.9mm with a 1.3 mm more opaque center	7.5	1.047	Progressive dissolution until day 42	6 on day 56	1.045 on day 56	Partial
8	3	MC	DLH	6.8	8	+	+	–	Too numerous to count, round cystic calculi, the largest measuring 8 mm in diameter	6.5	1.047	28	6	1.058	Complete
9	7	FS	DSH	5.5	7	+	–	–	One discoid cystic calculus, measuring 5.09 mm × 2.38 mm	6.5	1.039	14	6.5	1.051	Complete

BCS = body condition score; USG = urine specific gravity; FS = female spayed; DSH = domestic shorthair; FI = female intact; MC = male castrated; DLH = domestic longhai; + = present; – = absent

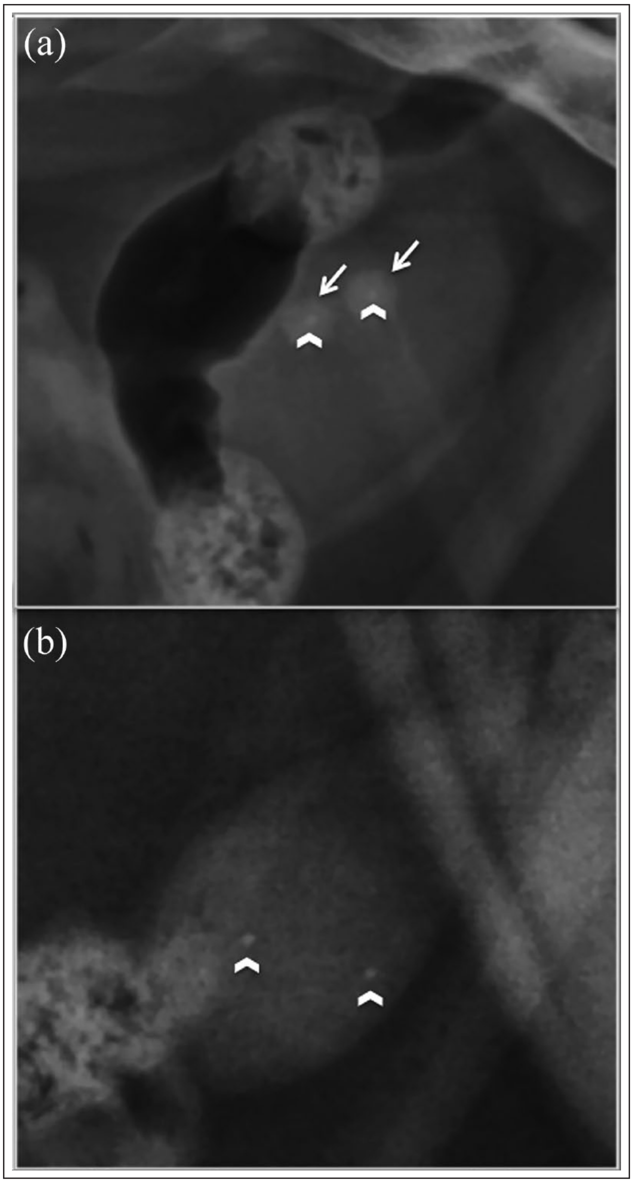

Figure 1 (a) Screening radiograph from a cat with suspected struvite cystolithiasis. Two mineral opaque calculi are within the urinary bladder. White chevrons highlight the central more radiopaque cores of the calculi. The white arrows show the peripheral less radiopaque shells of the calculi. (b) Sixty days later: the peripheral, less radiopaque shells of the calculi are no longer identifiable and the white chevrons highlight the remaining, unchanged more radiopaque cores of the calculi

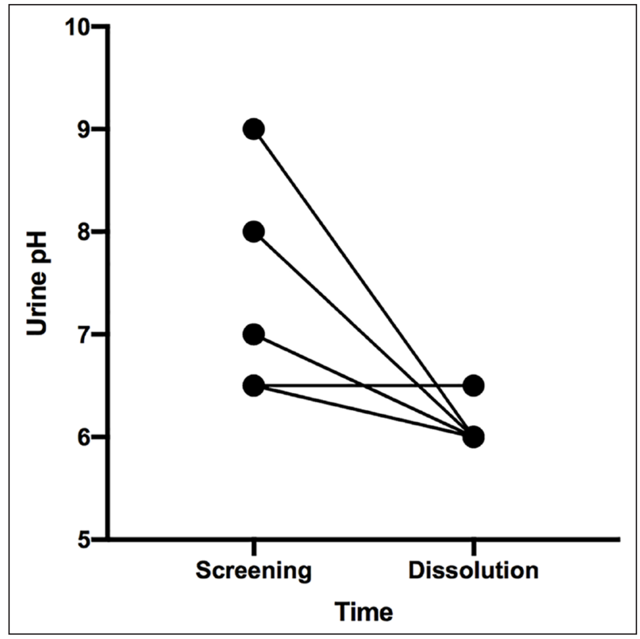

Figure 2 Urine pH at screening and at complete dissolution in seven cats for which it was available. Some of the study cats had identical pH values at screening or at dissolution. Time to dissolution varied between study cats

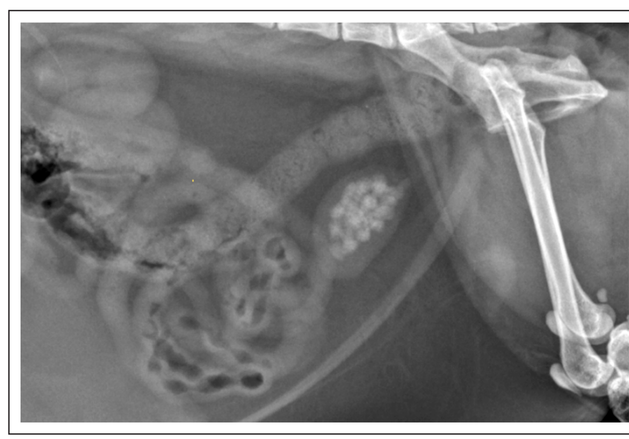

Figure 3 Screening radiograph from a cat (#4) with a large burden of suspected struvite cystolithiasis. Complete dissolution of the cystic calculi was observed at 70 days of feeding the test diet

In the cats for which complete dissolution of uroliths took longer than 14 days, radiographs revealed progressive reduction in urolith size and number at each subsequent recheck. As the uroliths became smaller, they often appeared to become less radiopaque. In the cat that did not experience complete radiographic dissolution, there were initially two moderately opaque cystoliths present. The center of the stones was more radiopaque than the periphery. As mentioned previously, these two stones had progressive reduction in size at the first two rechecks, but then remained static in size and mineral opacity.

Based on clinician preference, the enrolled cats were prescribed gabapentin for treatment of urinary pain or for sedation prior to recheck appointments. In addition, six cats required sedation for radiographs. The sedation protocol was up to clinician preference, but included use of one or more of the following: alfaxolone, butorphanol, dexmedetomidine (reversed with atipamezole when used), ketamine and midazolam. One cat was receiving amoxicillin–clavulonic acid at the time of study screening, but this was discontinued prior to enrollment per referring veterinarian treatment plan.

The owners of the nine cats completing the trial were contacted 6 months following complete stone dissolution or cystotomy. Eight of the nine cats were still eating the study diet. One of the nine cats (11%) was reported to have recent onset of lower urinary tract signs similar to those at the time the cystoliths were discovered, including periuria and hematuria. The owner reported that the cat was still eating the study diet, but was also being given additional food items as treats. Attempts were made to follow up and determine the cause of the lower urinary tract signs, but these were unsuccessful. All other cats were free of lower urinary tract signs.

Discussion

This study demonstrates that the investigated diet can assist in successful dissolution of suspected struvite cystoliths in cats. The diet was accepted and well tolerated, with only one cat failing to consume an adequate amount to maintain weight.

Prediction of cystolith type in the cat is challenging at best. Unlike dogs, struvite cystoliths in cats are not generally associated with a urinary tract infection with urease-producing bacteria and may appear less radiopaque than calcium oxalate cystoliths.[15] The urine pH may also be lower in the presence of a struvite cystolith than what is normally found in a dog with an infection-induced struvite urolith.[16] Struvite does not necessarily form the large concretions often seen in the dog. When evaluating cases for the presence of struvite uroliths, we used urine pH, moderate mineral opacity, lack of hypercalcemia and lack of evidence of mineralization in the kidneys or ureters as our guides. Based on these criteria, we had relative success identifying cats that had cystoliths amenable to dissolution with this diet. Calcium oxalate cystoliths do not appear to dissolve with dietary manipulation, urate stones are relatively uncommon in the cat and other types of cystoliths are considered very rare. It is therefore reasonable to assume that the stones that were dissolved in these patients were struvite.

Investigators have reported that between 1.0% and 3.3% of analyzed uroliths are compound in nature with one mineral type as the core or nidus, and another forming a shell.[5,17] We suspect this was the case with one of our study participants. The cat had two large cystoliths that had more mineral opaque cores, easily visible on screening radiographs. As the outer shell dissolved, the appearance of these cores did not change. When the two cystoliths were removed after no change for several weeks, they were found to be calcium oxalate with a light layer of struvite crystals on one of them. This supports our theory that these were compound cystoliths with a calcium oxalate core and a thick struvite shell. There is value in attempting to dissolve suspected struvite outer layers, even if the core may be of a different material. If the insoluble core is small enough, and the cat is female or a male with a perineal urethrostomy, they may be removed using voiding urohydropulsion instead of more invasive surgical techniques. Being a male, however, this cat still needed to have the smaller nidi removed surgically.

Previous studies evaluating maintenance dissolution diets have reported mean times to radiographic dissolution of 13 days (range 7–14),[18] 13 days (range 6–28),[19] 27 days (range 7–52)[19] and 30 days (range 14–56).[20] One study reported a median time to radiographic dissolution of 18 days (range 10–55).[12] Time to dissolution of the cystoliths using the diet evaluated here was comparable to these diets. One partial responder at day 56 initially had a very large stone burden and did continue to show radiographic improvement at each time point during the study. It is widely thought that the effect of urine concentration and pH are the two most important factors in promoting struvite dissolution. This cat had a urine pH of 6.5 at screening and a pH of 6.0 throughout the study, indicating sufficient acidification for dissolution; however, its USG, which was 1.020 at screening, was >1.050 while being fed the test diet. The high USG was not unique to this cat, and several were >1.050 at each time point and yet still experienced shorter dissolution times.[21] This may support the possibility that the large stone burden was the cause of prolonged dissolution. Many of the previous studies evaluating dietary dissolution of struvite stones did not report the stone burden of the cats.[8,12,15,22] In two studies, stone burden was reported and none of their cats had as large a stone burden as the patient in this study.[18,19] Initial urolith size has been positively correlated with time to complete dissolution in a previous study, but it is unknown if a larger number of smaller uroliths creating a large stone burden affects dissolution time the same as a single large stone.[19] It is also possible that the owner was non-compliant with the instructions to feed only the test diet; however, at each recheck the client activity and feeding logbook indicated compliance with the guidelines for the study.

Urine pH significantly influences the solubility of struvite cystoliths, with urine acidification being a major factor in their medical dissolution. In a recent study evaluating the efficacy of a dissolution diet in dogs with presumed infection-induced struvite cystolithiasis, the median pH at diagnosis was 7.9. In that study, the median urine pH at completion in responders was 6.73, significantly lower than at baseline.[23] The median pH at screening in the complete responder cats on the present study was 7.0, with a significant but clinically minor decline to 6.0 at the time of complete dissolution. This implies that sterile struvite cystoliths in cats can form at a lower pH than infection-induced struvite cystoliths in dogs, and that their dissolution may be more dependent on other factors such as the presence of calculogenic inhibitors and absence of promotors. The high urine pH level at which dogs form infection-induced struvite uroliths is likely due to bacterial urease production. In cats, high levels of phosphorus and magnesium in the diet increase the risk of struvite urolithiasis, and feeding a diet lower in these minerals may be more important than further acidification if the urine pH is already <7.0.[24]

We found that monitoring of urine pH was a useful indicator of dietary compliance. In the one cat eliminated from the study owing to dietary non-compliance, the screening pH was 7. On day 14 the pH was 6.5 and on day 28 the pH was 6. There was progressive decrease in urolith size and mineral opacity at these visits. On the day 42 visit, the owner indicated the cat had been fed powdered doughnuts by a visiting family member in addition to the study diet. The urine pH at this time was 8. There was also a concomitant increase in size and mineral opacity of the uroliths.

Dilution of the urine in a dog or cat with any type of urolithiasis has been a long-held standard of care. Many dissolution and prevention diets aim to lower the USG of the patient through a variety of means. In this study, however, the USG was not significantly different among responders between screening and at complete dissolution. Thus, the role of urine dilution, while important, may not be as key in the treatment of feline struvite uroliths as previously thought, as long as an appropriate urinary RSS is achieved.[25]

Increased BCS has been identified as a risk factor for the development of urethral obstruction.[10] It is hypothesized that the same excess consumption of food that leads to weight gain could also result in an excess consumption, and therefore excretion, of minerals, which may be calculogenic.[6] Indeed, in this study BCS was not a selection criterion, but most of the cats enrolled were overweight or obese. In fact, the majority of cats in the study were BCS 8 or 9. This reinforces the need to address weight management in cats prone to the development of struvite calculi as part of long-term prevention.

One of the three cats that were removed from the study developed a urethral obstruction with a struvite urolith. Male cats are more likely to develop urethral obstruction by cystoliths; however, the cat in this study was female. The risk of a dissolving struvite cystolith shrinking to a size that can enter the urethra and become obstructive is recognized;[9] however, it has not been commonly reported. Radiographic dissolution of the cystoliths was occurring in this cat until the time of obstruction, and it seems likely that it would have otherwise continued to complete resolution without the adverse event.

One cat was removed from the study due to systemic illness. While a final diagnosis was not made in the case, there is no evidence the feeding of the study diet or the presence of the cystoliths played a role. The cat was transitioned to the study diet over 1 week, then ate the calculated amount of study diet for the next week. During the following week, the cat became lethargic and progressively hyporexic. The owner offered small amounts of the old diet, which the cat partially consumed. The cat was also receiving gabapentin for urinary pain. At the day 14 recheck, the cat had lost 1.0 kg since screening (11% of its initial body weight). On bloodwork, the significant abnormality compared with screening was moderate hyponatremia (122 mmol/l). Hyponatremia had not been found in other cats on the study diet, and the diet meets the AAFCO recommendations for sodium content. Therefore, it was believed some other disease process, such as hypoadrenocorticism, pyelonephritis or the syndrome of inappropriate antidiuretic hormone secretion, was responsible for the hyponatremia. Additionally, in humans, gabapentin has been occasionally reported to cause hyponatremia.[26] The owner declined further diagnostics to investigate the underlying cause of the cat's illness.

There are several limitations to this study. Radiographic evidence of dissolution was used, rather than the more sensitive mode of ultrasound. This was chosen because most general practitioners may not have access to an ultrasound and therefore would monitor dissolution using radiography. In addition, if cystoliths were too small to be detected by radiography, they would likely be small enough to be voided and thus would not require further dissolution therapy.

Some studies of dissolution diets have used weekly imaging to evaluate cystolith dissolution.[12,18,19,22] More frequent radiographic evaluation may have given a more accurate time to complete dissolution; however, previous studies have used 14-day intervals to assess dissolution.[16,20] In addition, the difficulty of recruiting cases to the study may have been increased by the need for more frequent visits.

Some cats had a 1-week transition to the test diet before the study period began, whereas other cats started the test diet and study period immediately. Sudden diet changes can be stressful to cats, which is why a transition was chosen for some patients.[27] If dissolution began during this transitionary period, our study may be underreporting the time to dissolution. However, the authors believe it is unlikely that stone dissolution would have begun during the transitionary period. The addition of other foods would affect the balance of phosphorous and magnesium consumed and, in turn, alter the amount excreted.[25,28,29] This may raise the urine RSS, so that the test diet would not function as designed. For example, the cat that was withdrawn from the study for consuming food other than the test diet had a steady reduction in stone density and size while exclusively eating the diet. However after being fed doughnuts in addition to the test diet, the stones actually increased in size and density.

Clients were contacted 6 months after completing the study to determine if the cats were still consuming only the test diet and whether they had demonstrated clinical signs of recurrence. Two previous studies also followed up with patient examinations at varying time points for up to 6 months.[16,18] The follow-up with a phone call and not a recheck visit with radiographs and urinalysis as well as physical examination may have missed asymptomatic cystolith recurrence in the patients in this study and is a limitation on the assessment that the diet was adequate for prevention. However, as an effective dissolution diet, it is highly likely that if fed exclusively as directed it would also prevent recurrence.

Another limitation of this study was that the urine pH was determined by reagent test strip instead of a pH meter. Many commercial labs, including those at the institutions where this study was performed, use this method. Inaccuracy of pH measurement using reagent test strips compared with a pH meter has been documented with a bias toward over-estimation of pH by the test strips.[30] It is possible that the pH of the urine was lower at the various time points than reported; however, the same method of pH testing was used at all time points for all cats.

Finally, the small number of cases enrolled and completing the study may have masked the presence of more partial or even non-responders that had struvite uroliths. However, each of the nine cats completing the study had substantial and clinically relevant radiographic dissolution of their uroliths that were suspected to be composed of struvite, which indicates the efficacy of the diet when fed exclusively.

Conclusions

The test diet was successful in dissolving suspected struvite cystoliths in 28 days or less, as well as maintaining remission of cystolith-induced lower urinary tract signs in the majority of cats studied. As this diet is suitable for maintenance feeding of adult cats, it may be a suitable choice for long-term prevention of feline struvite urolithaisis.

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Author note The results of this study were presented in part, as a poster abstract, at the American Academy of Veterinary Nutrition Clinical Nutrition & Research Symposium, online meeting, 2020.

Supplementary material The following files are available online:
Supplementary material 1: ingredient list for test diet.
Supplementary material 2: average nutrient analysis for test diet.

Conflict of interest Drs Daristotle, Carmella and Frantz are employees of the Blue Buffalo Company.

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Ethical approval This work involved the use of non-experimental animals only (including owned or unowned animals and data from prospective or retrospective studies). Established internationally recognized high standards ('best practice') of individual veterinary clinical patient care were followed. Ethical approval from a committee was therefore not necessarily required.

Informed consent Informed consent (either verbal or written) was obtained from the owner or legal custodian of all animal(s) described in this work (either experimental or non-experimental animals) for the procedure(s) undertaken (either prospective or retrospective studies). For any animals or humans individually identifiable within this publication, informed consent for their use in the publication (verbal or written) was obtained from the people involved.

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