Composition and characteristics of urinary calculi from guinea pigs

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Objective—To determine the mineral composition of calculi, anatomic locations of the calculi, and findings of urinalysis and bacteriologic culture of urine and calculi in guinea pigs with urolithiasis.

Design—Cross-sectional study.

Animals—127 guinea pigs.

Procedures—Records of urinary calculi that had been submitted to the University of California Stone Laboratory from 1985 through 2003 were reviewed. In addition, submissions of urinary calculi for evaluation by the laboratory were prospectively solicited from 2004 through 2007. Prospectively obtained calculi were accompanied by a urine sample for urinalysis and a completed questionnaire. All calculi were analyzed by use of polarized light microscopy and infrared spectroscopy. A subset of calculi was examined by means of x-ray diffractometry (XRD).

Results—83% (43/52) of calculi from the laboratory database and 93% (70/75) of calculi that were prospectively solicited were composed of 100% calcium carbonate. Analysis via XRD confirmed that 5 of 6 calculi from a subset that had the greatest gross morphologic variation were composed of 100% calcite. Although many guinea pigs had received antimicrobials before bacteriologic cultures of urine were performed, Corynebacterium renale was isolated from 5 urine samples.

Conclusions and Clinical Relevance—Contrary to findings of other studies, urinary calculi analyzed for the present study were most commonly composed of 100% calcium carbonate, and infrared spectroscopy or XRD was necessary to differentiate this mineral from others. Treatments, including diet and husbandry practices, should be developed to help prevent development of calcium carbonate calculi in guinea pigs. (J Am Vet Med Assoc 2009;234:214–220)

Urolithiasis is a common health problem in many species including guinea pigs (Cavia porcellus). Historically, middle-aged to older (ie, >2.5 years of age) females were believed to be overrepresented among affected guinea pigs. To date, the etiopathogenesis of urolithiasis in guinea pigs is unknown. Of the very few published reports of this disease in guinea pigs, most are case reports. Historical information and anecdotal reports have suggested that calcium oxalate calculi are the most common type of calculi identified in guinea pigs, but the methods of analysis of calculus composition in early reports are not provided. However, in a recent retrospective study in which the composition of 20 urinary calculi from pet guinea pigs was evaluated by means of infrared spectroscopy, investigators found that all 20 calculi contained multiple mineral types, with 18 (90%) calculi containing calcium carbonate, 12 (60%) containing calcium phosphate, 10 (50%) containing struvite, and only 3 (15%) containing calcium oxalate. Also, in the 2 most recent case reports of urolithiasis in guinea pigs, the composition of calculi as determined via XRD was 100% calcium carbonate.

It has been suggested that urinary tract infections involving Escherichia coli, Streptococcus pyogenes, and Staphylococcus spp are associated with the existence of urinary calculi in laboratory guinea pigs, but to our knowledge, similar findings in pet guinea pigs have not yet been reported. Determining the composition of the urinary calculi from affected guinea pigs and the existence of a urinary tract infection at the time of calculus removal is important for establishing the etiopathogenesis of this disease, which in turn may provide information to improve future treatment options.

The purpose of the study reported here was to determine the mineral composition of calculi, anatomic locations of the calculi, and findings of urinalysis and bacteriologic culture of urine and calculi in guinea pigs with urolithiasis. In addition, we sought to determine whether a certain breed, age, sex, or reproductive status was overrepresented among affected guinea pigs.

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CFU</td>
<td>Colony-forming unit</td>
</tr>
<tr>
<td>FTIR</td>
<td>Fourier-transform infrared</td>
</tr>
<tr>
<td>rDNA</td>
<td>Ribosomal DNA</td>
</tr>
<tr>
<td>rRNA</td>
<td>Ribosomal RNA</td>
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<td>XRD</td>
<td>X-ray diffractometry</td>
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Materials and Methods

Sample submission—All records of guinea pig urinary calculi that were submitted to the Gerald V. Ling Urinary Stone Analysis Laboratory from 1985 through 2003 for crystallographic analysis were reviewed and included in the study. In addition, during 2004 through 2007, multiple veterinary medical practices and institutions participated in the submission of urinary calculi from guinea pigs with urolithiasis. Six geographic regions, which included all 50 US states, were selected on the basis of a combination of regions defined by the AVMA, as described elsewhere.3 For this study, a seventh region was added to include calculi submitted from outside the United States. Staff members of participating institutions were asked to submit calculi on ice to the laboratory via overnight delivery. In addition to the calculi, staff members were asked to submit a urine sample for bacteriologic culture, results of urinalysis, and a completed questionnaire that requested information on the signalment of affected guinea pigs (breed, age, sex, and reproductive status) and the anatomic location of the calculus at the time of removal.

Analysis of urinary calculus—All calculi received by the laboratory were weighed, size was measured, and the gross crystalline morphology (ie, color, shape, and surface texture) was determined by use of a stereoscopic dissecting microscope.4 Samples from each visible layer of each calculus were examined separately by means of the oil immersion method of optical crystallography via a polarized light microscope5 to determine mineral composition and estimate the relative volumetric percentages of the minerals in each layer of the calculus. To examine calculi that were homogenous in gross crystalline morphology throughout the cross section of the specimen, samples for analysis were obtained from the surface layer, outer portion, and core. Every sample was tested for carbonate by placing a portion of ground calculus from each layer on a porcelain spot test plate, adding 2 drops of 1M HCl, and observing for effervescence. Effervescence with HCl indicated the existence of carbonate in the specimen.

Analysis by means of FTIR spectroscopy and XRD—After initial examination with polarized light microscopy, each calculus was analyzed for chemical composition by use of an FTIR spectrometer equipped with spectroscopy software6 and the kidney stone library and analysis software,7 as reported elsewhere.8 Six calculi identified by FTIR spectroscopy to be composed entirely of calcium carbonate and that had the greatest variation in gross crystalline morphology were chosen to be evaluated by means of XRD for the purpose of identifying the calcium carbonate minerals that each calculus contained. The mineralogy was determined via XRD analysis by use of a diffractometer8 equipped with a copper tube X-ray source (settings, 45 keV and 40 mA). Procedures used for specimen preparation and analyses have been described elsewhere.9

Bacteriologic culture of calculi—To prepare calculi for aerobic bacteriologic culture, each calculus was put through a series of washes with 50 mL of sterile saline (0.9% NaCl) solution, and 0.1 mL of the solutions from the first and fourth washes was streaked onto a defibrinated 5% sheep blood agar plate. Each calculus was removed from the fourth wash and gently rinsed again with sterile saline solution. Each calculus was then cracked with Ronguer forceps, and a small amount of the center of the calculus was removed with a sterile dental explorer, crushed in a sterile mortar and pestle, and mixed with 1 mL of sterile saline solution. One tenth of a milliliter of the resulting slurry was streaked onto a defibrinated 5% sheep blood agar plate. Inoculated agar plates were incubated at 37°C (98.6°F) and monitored for bacterial growth as described elsewhere.10

Morphology of bacterial colonies was recorded, and growth was quantified or semiquantified according to standard laboratory protocols. Growth of > 10^8 CFU/mL from a calculus specimen was considered important.

Bacteriologic culture of urine and tissues—Submitted specimens of urine and urinary bladder wall and swab specimens obtained from urinary bladders were processed for aerobic bacteriologic cultures. Specimen type, method of specimen collection, and any treatment of guinea pigs with antimicrobials at the time of specimen collection were recorded. Urine samples were inoculated onto sheep blood agar and MacConkey agar plates by use of a quantitative loop method, with a loop calibrated to deliver 0.01 mL. Plates were incubated in 5% carbon dioxide at 37°C and examined daily for growth for 5 days. Morphology of bacterial colonies was recorded, and growth was quantified or semiquantified according to standard laboratory protocols. Swab specimens obtained from urinary bladders were inoculated directly on both types of agar and examined for growth in the same manner. Biopsy specimens of urinary bladder wall were placed in brain-heart infusion broth and macerated with a tissue grinder; 1 or 2 drops of this emulsion were streaked onto 5% sheep blood agar and Brucella base 5% sheep blood agar prior to aerobic and anaerobic incubation at 35°C. Growth of > 10^8 CFU/mL from the specimens of urine and urinary bladder wall was considered a positive culture result.

To confirm the identity of some bacterial isolates, partial 16S rRNA gene sequencing was used.11 Briefly, DNA was extracted by suspension of bacterial colonies in 2% SDS and 10% Triton X-100 in Tris-EDTA buffer (pH, 8.0), heating at 98°C (208.4°F) for 5 to 15 minutes, and cooling at 4°C (39.2°F) for 1 minute, followed by centrifugation to pellet bacterial debris.12 The supernatant was used as a template for 16S rDNA amplification by means of a PCR master mix and universal 16S rDNA primers 8FPL (5′–CTGGAGAGTTGTAGCCCTGGCAG–3′) and 1492RPL (5′–CGGGTACCTTGTTACGACTT–3′), as described elsewhere.13 The PCR product was purified and concentrated via ultrafiltration by use of a centrifugal filtration unit.14 Amplified DNA was sequenced in 1 direction with one of the aforementioned primers by means of dye terminator cycle sequencing with an automated DNA sequencer.15 The resulting sequence was compared with other DNA sequences in the GenBank database16 for identification of bacterial genus, species, or both.

Statistical analysis—The propensity for either males or females to have a higher-than-expected frequency of stone submission for identification was evaluated by means of a χ^2 test. Summary statistics for continuous variables are reported as mean ± SD, except where otherwise indicated.
Results

For the retrospective portion of the present study, 52 records of guinea pigs and their urinary calculi from the laboratory database were available for review. These calculi originated from the following regions in the United States: California (n = 30 [58%]), mountain or Pacific (3 [6%]), north central (2 [4%]), south central (4 [8%]), New England or mid Atlantic (7 [13%]), and south Atlantic (6 [12%]).

Age at the time of calculus removal was recorded in years for 46 (88%) guinea pigs. Median age was 3 years (range, 0.5 to 5 years). Breed and body weight information was not available. Thirty-three calculi originated from males, and 19 calculi originated from females; the reproductive status of these guinea pigs was not routinely provided. Thirty-seven (71%) of these calculi had been removed from the urinary bladder, 9 (17%) were from the urethra, 3 (6%) were from the urinary bladder and urethra, 2 (4%) were from the ureter, and 1 (2%) was from the vagina. Three calculi from male guinea pigs were located in the urethra, 2 were located in a ureter, and the rest were removed from the urinary bladder. Six calculi from female guinea pigs were located in the urethra, 1 calculus was in the vagina, and the remaining calculi were obtained from the urinary bladder.

As revealed by a combination of the aforementioned analytic techniques, 43 (83%) calculi were composed of 100% calcium carbonate. Six had calcium carbonate in combination with other minerals, including struvite (n = 4 calculi), apatite (1), and calcium oxalate dihydrate (1). Three calculi were of unknown composition; all 3 had been submitted in the early 1980s.

For the prospective portion of the study, 75 calculi from affected guinea pigs were submitted from 2004 through 2007. These calculi originated from the following regions in the United States: California (n = 17 [23%]), mountain or Pacific (8 [11%]), north central (19 [25%]), south central (7 [9%]), New England or mid Atlantic (14 [19%]), and south Atlantic (5 [8%]). An additional 5 (7%) calculi were received from veterinary medical institutions from the United Kingdom (n = 4) and Nova Scotia (1).

The number of submissions from male and female guinea pigs for the prospective study was not significantly different: 38 (51%) were from intact males, 6 (8%) were from castrated males, 25 (33%) were from intact females, and 6 were from spayed females. Mean ± SD age (recorded in months) for all guinea pigs was 44.5 ± 20.5 months (range, 10 to 102 months); for the sexually intact and spayed females, age was 45 ± 18.3 months and 57.2 ± 27.6 months, respectively; and for sexually intact and castrated males, age was 38.6 ± 13.7 months and 41.5 ± 14.2 months, respectively. Breeds of guinea pigs for which breed information was available (n = 28 [37%]) were American Smooth-Coated (13), Peruvian (6), Abyssinian (4), Teddy (2), American Crested (1), English Crested (1), and English Smooth-Coated (1). Mean ± SD body weight of all guinea pigs was 987.3 ± 183.5 g (2.2 ± 0.4 lb). Body weights of the sexually intact and spayed female guinea pigs were similar (931.2 ± 182.6 g [2.0 ± 0.4 lb] and 935.0 ± 271.5 g [2.1 ± 0.6 lb]) to the body weights of the sexually intact and castrated males (1,026.3 ± 198.2 g [2.3 ± 0.4 lb] and 1,026.7 ± 144.4 g [2.3 ± 0.3 lb], respectively).

Forty-five (60%) calculi were obtained from the urinary bladder, 20 (27%) were removed from the urethra, 3 (4%) were passed spontaneously by the guinea pigs, 3 were removed from a ureter, 1 (1%) was removed from the vagina, 1 was removed from both the urinary bladder and ureter in 1 guinea pig, and 1 was removed from both the urinary bladder and kidney in another guinea pig. A location was not provided for 1 calculus. For the 44 male guinea pigs, 31 (70%) calculi were located in the urinary bladder, 8 (18%) were in the urethra, 3 (7%) were in the ureters, 1 (2%) calculus was passed spontaneously, and 1 calculus was removed from both the urinary bladder and ureter.

For the 31 female guinea pigs, 14 (45%) calculi were located in the urinary bladder, 12 (39%) were in the urethra, 2 (6%) were passed spontaneously, 1 (3%) was in the vagina, 1 was removed from both the urinary bladder and kidney in 1 guinea pig, and 1 was removed from an unknown location. Similar to the results of the retrospective portion of the study, ureteral calculi were collected only from male guinea pigs.

As revealed by a combination of analytic techniques, 70 (93%) calculi were composed of 100% calcium carbonate. Four had calcium carbonate in combination with 1 other mineral, including struvite (n = 3 calculi) and apatite (1). One calculus was composed of a mixture of calcium carbonate, apatite, and calcium oxalate dihydrate.

Stereoscopic microscopy revealed that the surfaces of all calculus specimens were roughly textured with fine crystals visible and varied from light tan to medium tan in color (Figure 1). The initial examination of each calculus specimen performed by use of the oil immersion method of optical crystallography was inconclusive. Therefore, the chemical test for carbonate was per-
formed, revealing that all calculi contained carbonate. Infrared spectroscopy confirmed the percentage of calcium carbonate in each specimen.

Five of the 6 calculus specimens that were analyzed by means of XRD were composed entirely of the mineral calcite (calcium carbonate; Figure 2). In addition to a peak for calcite, an additional peak representing monohydrocalcite (calcium carbonate hydrate) was detected in 1 specimen (Figure 3). No other minerals were detected in these 6 specimens.

Results of urinalysis performed at the time of calculus removal were available for 44 of the 75 guinea pigs in the prospective portion of the study. Mean urine specific gravity was 1.015 ± 0.008 (range, 1.004 to 1.046), and mean urine pH was 8.4 ± 0.5 (range, 6.3 to > 9.0). Microscopic hematuria (> 4 RBCs/hpf; 8 males and 6 females) and pyuria (> 5 WBCs/hpf; 3 males and 6 females) were the most commonly reported abnormalities, followed by mucus (2 males and 1 female) and lipid droplets (2 males and 3 females; Table 1). Crystals in urine sediment were reported for 21 guinea pigs. Seven (33%) specimens contained calcium carbonate crystals, 3 (14%) contained magnesium ammonium phosphate crystals, 3 (14%) contained amorphous phosphate crystals, and 2 (10%) contained calcium oxalate crystals. Crystalluria was not evident in 6 (14%) samples. Data from sediment evaluation were reported for 23 guinea pigs. Fourteen of the urine samples for which sediment data were available were collected via sterile methods; rare to moderate numbers of bacteria were evident in 4 of these samples, although the type of bacteria (cocci or rods) was not reported.

Sixty-eight specimens obtained from the lower urinary tracts of 59 of 75 (79%) guinea pigs were submitted for bacteriologic culture. Nonsterile or unidentified specimens accounted for 12 of the submitted specimens; these 12 were therefore excluded from data analysis, reducing the number of accepted samples from 56 to 47 guinea pigs. Antimicrobials had commonly been administered to the guinea pigs at the time specimens were collected. Enrofloxacin and trimethoprim-sulfadiazine were by far the 2 most commonly administered antimicrobials. Only 2 guinea pigs were treated with other antimicrobials at the time of calculus removal: 1 received chloramphenicol, and the other received doxycycline.

Bacterial growth (> 10³ CFU/mL) was achieved from samples obtained from 8 guinea pigs: 4 sexually intact males, 2 sexually intact females, and 2 spayed females. Seven of 44 (16%) urine samples and 2 of 12 bladder wall specimens yielded bacterial growth (Table 2). Growth of 1 bacterial species was identified in only 3 urine samples and 2 bladder wall specimens. Corynebacterium renale was identified in 2 urine samples and both positive bladder wall specimens; one of the specimens originated from a guinea pig from which pure growth of C. renale was also obtained via bacteriologic culture of urine. Facklamia sp was identified by means of partial DNA sequence from bacteria isolated from 1 urine sample. Bacteriologic culture of the other 4 urine samples yielded mixed bacterial growth, including C. renale, Streptococcus bovis (equinus group), and Staphylococcus spp. Three guinea pigs with positive results for bacteriologic culture of urine and 1 guinea pig with a positive result for bacteriologic culture of the urinary bladder wall had been treated with antimicrobials at the time the specimens were obtained. Contaminant con-
centrations of bacteria were identified in 3 of 44 (7%) urine samples and 3 of 12 bladder wall specimens. Negative results of bacteriologic culture were reported for 34 of 44 (77%) urine samples, 7 of 12 bladder wall specimens, and 5 of 5 bladder swab specimens. Fifteen of those 34 (44%) urine samples and 4 of those 7 bladder wall specimens had been obtained while the respective guinea pigs were receiving antimicrobials.

The centers of 70 of 75 (93%) calculi were processed for bacteriologic culture; 5 calculi were not processed because of the small size of the available specimen. Positive bacterial growth was obtained from 5 of the 70 (7%) calculi. Growth of 1 bacterial species was obtained from the centers of 3 calculi; 2 had positive culture results for *Streptococcus viridans*, and 1 had positive culture results for *Proteus mirabilis*. *Streptococcus viridans* and *Staphylococcus* spp (coagulase negative) were isolated from 1 specimen; results for bacteriologic culture of specimens of urine and urinary bladder wall for the same guinea pig were negative. *Escherichia coli* and *Enterococcus* spp were isolated from the calculus of another guinea pig that also had negative results for bacteriologic culture of specimens of urine and urinary bladder wall. Specimens of urine or urinary bladder wall were not submitted for culture for 2 of the guinea pigs from which positive results for bacteriologic culture of calculi were obtained. One urine sample acquired during natural voiding that was excluded from evaluation had been obtained from another guinea pig from which positive results for bacteriologic culture of a calculus was obtained.

**Table 2—Results of microbiologic culture of specimens obtained from the urinary tracts of 47 guinea pigs with urolithiasis.**

<table>
<thead>
<tr>
<th>Specimen and collection method</th>
<th>Total No. of samples</th>
<th>No. of culture-positive specimens</th>
<th>No. (%) of guinea pigs that received antimicrobials when positive specimen was submitted</th>
<th>No. of culture-negative specimens</th>
<th>No. (%) of guinea pigs that received antimicrobials when negative specimen was submitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine</td>
<td>8</td>
<td>2</td>
<td>2 (100)</td>
<td>6</td>
<td>3 (50)</td>
</tr>
<tr>
<td>Intraoperative cystocentesis</td>
<td>30</td>
<td>5</td>
<td>1 (20)</td>
<td>24</td>
<td>14 (58)</td>
</tr>
<tr>
<td>Cystocentesis</td>
<td>1</td>
<td>0</td>
<td>0 (0)</td>
<td>1</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Urinary catheter</td>
<td>5</td>
<td>0</td>
<td>0 (0)</td>
<td>3</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Bladder swab</td>
<td>12</td>
<td>2</td>
<td>1 (50)</td>
<td>7</td>
<td>5 (71)</td>
</tr>
<tr>
<td>Bladder wall biopsy</td>
<td>70</td>
<td>5</td>
<td>4 (80)</td>
<td>65</td>
<td>31 (48)</td>
</tr>
</tbody>
</table>

Discussion

Of all calculi obtained from guinea pigs in the study reported here, the majority (> 88%) were composed solely of calcium carbonate. This finding contrasts with other findings that the mineral composition of calculi obtained from guinea pigs is primarily calcium oxalate. Differences in calculus composition are likely attributable to the methods used to identify the various crystalline components.

Occasionally, as with calcium carbonate calculi from the guinea pigs, the oil immersion method of optical crystallography alone is insufficient for a definitive identification of the crystalline material in a calculus specimen. To differentiate the calcium carbonate crystals in urinary calculi from calcium oxalate monohydrate crystals, additional methods are needed. Calcium carbonate and calcium oxalate monohydrate crystals have similar microscopic characteristics. Both are birefringent; light passing through the crystals is refracted in 2 slightly different directions, and the crystals appear brightly colored under polarized light. Calcium oxalate monohydrate and calcium carbonate have a similar blue-red appearance under polarized light. In addition, the refractive indices of calcium oxalate monohydrate (1.492 and 1.648) and calcium carbonate (1.487 and 1.695) are very similar; therefore, even matching the refractive indices is insufficient to definitively distinguish between the 2 mineral types.

A calculus that contains carbonate will effervesce with the addition of 1M HCl, whereas a ground calculus specimen composed of calcium oxalate monohydrate will not effervesce. However, whereas effervescence with HCl indicates the existence of carbonate, it does not exclude the coexistence of calcium oxalate; therefore, another method such as FTIR spectroscopy or XRD is needed to definitively identify the mineral components in a calculus.

Fourier-transform infrared spectroscopy determines the chemical composition but does not determine the crystalline structure. Calcium carbonate most often exists in the form of calcite but can exist as aragonite or vaterite, 2 other polymorphs of calcium carbonate that have the same chemical composition (CaCO₃) but different crystal structures, symmetries, and shapes. In time, aragonite and vaterite crystals may be transformed into calcite because calcite is the most stable form of calcium carbonate. Therefore, XRD was used to differentiate the different polymorphs or additional forms of calcium carbonate in the subset of calculus specimens we analyzed, and as expected, calcite was detected in all 6 samples. This finding is similar to that of another study in which calcite was the most common mineral form of calcium carbonate in urinary calculi from horses.

Information from other studies regarding signalment of affected guinea pigs suggested that older female guinea pigs were overrepresented among those from which urinary calculi were obtained. The ages of the guinea pigs in the present study were similar to those of other reports, with males just slightly, albeit insignificantly, younger than females. In the present study, 60% of submitted calculi were from male guinea pigs, but this number was not significantly different from the number of female guinea pig calculus submissions. A study in Germany revealed that 15 of 20 (75%) guinea pigs in which urinary calculi were diagnosed were female. The reason for these differences in distribution of sex among guinea pigs with
urinary calculi from the German study and those of our study is unclear. To our knowledge, no specific cause for the development of urolithiasis in female guinea pigs has been identified. Given the anatomy of the urinary tracts of male and female guinea pigs, it would be expected that male guinea pigs would be more prone to urinary obstruction attributable to urolithiasis, requiring veterinary intervention for urolith removal. This may have biased the number of antemortem specimens from male guinea pigs submitted to our laboratory, allowing for additional representation of male guinea pigs in our study.

Most (57%) of the calculi evaluated in the retrospective portion of the study were submitted from clients living in California. This is not surprising and likely reflects allegiance of clients in close proximity to our laboratory. Similar findings were reported for this laboratory for calculi from dogs. However, to minimize the potential for geographic bias, it was important to ensure that guinea pigs from all areas of the United States were represented. By soliciting calculi from across and outside the United States during the prospective portion of the study, submissions occurred from all regions, although the fewest numbers were from the south-Atlantic region. Predilections for urinary calculi among guinea pigs in certain geographic regions could not be investigated on the basis of only 75 calculi; however, what we could conclude was that the mineral composition of calculi did not appear to vary on the basis of region of origin.

To our knowledge, reference intervals for urinalysis have not been reported for healthy guinea pigs, making it impossible to compare and fully evaluate the values obtained for the guinea pigs with urinary calculi in the present study. The mean urine specific gravity of urine samples submitted from these guinea pigs was dilute. For humans with urolithiasis, and presumably for small animals, sufficient water intake is important for preventing calculi. It is unknown whether additional drinking water would have been of benefit to the guinea pigs in our study because their urine was already isosthenuric. Perhaps the lack of an unknown calculus growth inhibitor or the existence of an unknown growth promoter in the urine contributed to calcium carbonate formation as well. Similar hypotheses have been posited for the formation of calcium oxalate or urate calculi in other species of animals. A large proportion of urine samples with positive results for blood or protein as revealed via dipstick tests is not surprising in any animal with urolithiasis.

The sediment examination revealed various crystals in less than half of the urine samples that were analyzed and calcium carbonate crystals in only 33% of the samples in which crystals were reported. Therefore, the types of crystals detected during sediment examinations do not appear to predict the mineralogy of urinary calculi from guinea pigs. Similar findings are reported for other small animals. However, false-positive crystalluria could have resulted because in some of the guinea pigs in our study, urine may not have been evaluated within 30 to 60 minutes, which is the recommended time reported for other species of animals.

The incidence of bacterial cystitis was reported to be 17.7% females and 2.7% males in 1 population of guinea pigs. Reports also indicate that bacterial cystitis in female guinea pigs may be associated with the development of urolithiasis. Female guinea pigs are more prone to bacterial cystitis than male guinea pigs because the urethral opening is closer to the anus in females. This anatomic difference potentially allows gastrointestinal flora to ascend the urethra into the urinary bladder, where these bacteria could cause disease in certain conditions. Contrary to the findings in the aforementioned reports, males and females were equally represented among the positive results for bacteriologic culture of lower urinary tracts in our study.

Although many guinea pigs were receiving antimicrobials when specimens were submitted for bacteriologic culture, positive bacterial growth was identified in 16% of urine samples, 17% of urinary bladder wall samples, and 7.1% of the calculi subjected to bacteriologic culture in our study. Urinary tract infections involving E coli, S pyogenes, and Staphylococcus spp are associated with the existence of urinary calculi in laboratory guinea pigs, and these bacteria were infrequently isolated from the guinea pigs in our study. Corynebacterium renale was the most commonly identified bacteria. This bacterium is a large, irregularly staining, gram-positive bacillus with pili that allow the bacteria to adhere to the urinary tract. The organism is reported to produce urease, but it is unlikely that this species of Corynebacterium is a potent urease producer. If it were, one would expect there to be some struvite or calcium phosphate crystal formation similar to that often reported with C urealyticum infections in humans, dogs, and cats. To the authors’ knowledge, the clinical features and characteristics of C renale infections in guinea pigs have not been described in the veterinary literature. Corynebacterial necrohemorrhagic cystitis in 2 female macaques has been reported, but DNA typing of the bacterial species was not performed. It is unlikely that infection with C renale caused precipitation of the calcium carbonate crystals and calculus formation; urinary bladders were most likely compromised because of the calculi, and secondary bacterial colonization occurred.

Most of the calculi from guinea pigs in the study reported here were composed of 100% calcium carbonate. Calcium carbonate can be difficult to differentiate from calcium oxalate monohydrate by means of polarized light microscopy, and FTIR spectroscopy or XRD is needed to definitively identify calcium carbonate. Analysis via XRD revealed that calcite was the most common form of calcium carbonate in the calculi in our study. Although various types of crystals were detected in urine sediments, the calculi of all guinea pigs in our study contained calcium carbonate. Results of bacteriologic culture of specimens from lower urinary tracts were difficult to interpret because many guinea pigs were receiving antimicrobials at the time the specimens were obtained. Additional studies are needed to evaluate risk factors such as diet and environment so the pathophysiology of urolithiasis in pet guinea pigs can be better understood.

a. Model 569, American Optical Co, Buffalo, NY.
References