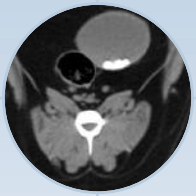

Diagnosis of Urolithiasis

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ABSTRACT: Diagnostic imaging is usually required to determine the presence of urolithiasis. Double-contrast cystography is more accurate than survey radiography and approximately as accurate as ultrasonography. Knowledge of the mineral composition of calculi helps direct appropriate management of urolithiasis, and signalment can help predict composition with about 70% accuracy. In cats, about half of cystic calculi are struvite and half are calcium oxalate; most nephroliths and ureteroliths are calcium oxalate. In female dogs, struvite uroliths are the predominant type found in the bladder. In male dogs, breed plays a strong role in prediction of bladder urolith type. It is difficult to predict the composition of nephroliths and ureteroliths based on signalment alone in dogs. Urinalysis and imaging findings can help in predicting urolith composition, although chemical analysis is necessary for definitive diagnosis.

Urolithiasis is a common problem in small animal practice. Although uroliths can be composed of different minerals, many of the associated clinical signs and diagnostic procedures are the same for all types. Knowledge of the specific mineral type is necessary for optimal management. Definitive mineral identification requires removal and chemical analysis; however, general epidemiologic patterns allow some predictions to be made.

EPIDEMIOLOGY

Cats

Between 89% and 96% of all feline uroliths submitted to urolith centers are composed of magnesium ammonium phosphate (struvite) or calcium oxalate.[1–3] Currently, struvite and oxalate uroliths occur in similar percentages in the feline urinary bladder.[1–3] An increase in oxalate uroliths from 1985 to 1994 may have been the result of widespread dietary acidification. Changes in dietary management, with less emphasis on urinary acidification, may have affected urolith composition in recent years.[1] In addition to calcium oxalate and struvite, the most common uroliths recovered from cats are urate (3% to 10%), calcium phosphate (0.1% to 6%), and dried, solidified blood calculi (1%).[1,2]

Most feline uroliths are retrieved from the bladder. Age and sex may help predict the composition of these calculi. Male cats are more likely to have oxalate than struvite uroliths (1.6:1).[1,2] Female cats are slightly more likely to have stru-

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Box 1. General Stone Composition Predictions for Cats and Dogs

Cats

- **Cystic calculi:** Almost equal distribution of calcium oxalate and struvite
- **Nephroliths and ureteroliths:** Most contain calcium; predominantly calcium oxalate

Dogs

In general, the composition distribution is similar between uroliths found in the upper urinary tract (nephroliths and ureteroliths) and those found in the lower urinary tract (cystic and urethral uroliths).

- **Females:** Most calculi are struvite (even in breeds predisposed to calcium oxalate) except in the following breeds:
  - — **Dalmatian:** Urate
  - — **Miniature schnauzer:** Equal proportions of calcium oxalate and struvite
- **Males:**
  - — **Breeds predisposed to oxalate:** Most likely calcium oxalate
  - — **Breeds predisposed to other stone types:** Most likely the predisposed stone type
  - — **Mixed breeds:** Equal distribution of calcium oxalate and struvite

vite than oxalate uroliths (1.2:1).[1,2] Younger cats (<4 years of age) are more likely to have struvite uroliths, cats 4 to 7 years of age have equal proportions of struvite and oxalate uroliths, and cats older than 7 years are more likely to have oxalate uroliths, but these differences are not dramatic.[1] Breed predilections have been noted, with oxalate uroliths being twice as common as struvite uroliths in Persians and Himalayans.[1,2] Urate uroliths are more common in Siamese cats than in other breeds.[1,2]

The number of uroliths recovered from the upper urinary tract has increased over the past 20 years.[4–6] This may be due in part to more aggressive surgical recommendations for urolith removal. However, the incidence of nephroureterolithiasis seems to be on the rise.[4–6] Most (75% to 87%) upper urinary tract calculi in cats are composed of calcium oxalate[1,5,6] (Box 1).

Approximately half of feline cystic calculi are composed of calcium oxalate and half are struvite.

Dogs

Between 80% and 91% of all uroliths submitted from dogs are struvite or calcium oxalate.[7–9] Similar to the situation in cats, the number of oxalate uroliths increased compared with struvite uroliths for a time, but proportions have stabilized in recent years.[7] Overall, there is a slight preponderance of struvite uroliths (44% to 45% of all urolith submissions) compared with oxalate (35% to 42%).[8,9] In dogs, the effect of sex is far more pronounced than it is in cats. Female dogs are 12 to 15 times more likely to have struvite uroliths, whereas male dogs are three times more likely to have oxalate uroliths.[7,8] Younger dogs are more likely to have struvite than oxalate uroliths.[7] Certain breeds are predisposed to developing urolithiasis (Table 1), but the interactions between breed, sex, and age complicate prediction of composition. In one study, an algorithm for predicting mineral type using signalment alone was accurate 70% of the time.[10] In contrast to cats, in which most upper urinary tract uroliths contain calcium, upper urinary tract uroliths in dogs are evenly distributed between struvite, calcium oxalate, and other urolith types[11–13] (Box 1).

DIAGNOSIS

History and Clinical Signs

Clinical signs of cystic calculi include hematuria, pollakiuria, stranguria, and dysuria, but these signs are also common with other diseases of the lower urinary tract. Small uroliths can cause partial or complete urinary obstruction of the urethra, leading to bladder distention, abdominal pain, paradoxical incontinence, stranguria, and signs of postrenal azotemia (anorexia, vomiting, depression). Occasionally, the bladder ruptures, resulting in uroabdomen.

With nephroliths and ureteroliths, the clinical history varies, and signs may be intermittent. The patient may be asymptomatic. Microscopic or macroscopic hematuria may be present. Signs associated with ureteral calculi are usually caused by renal dysfunction from concurrent pyelonephritis or obstructive uropathy (uremia). Abdominal pain may be present but does not seem to be a common finding.[5] In one study, almost half of the cats evaluated for chronic kidney disease had nephrolithiasis or ureterolithiasis.[4] The presence of con-

Table 1. Breed Predispositions for Uroliths[a,15]

	Urolith Type					
Breed	***Oxalate***	***Struvite***	***Urate***	***Cystine***	***Calcium phosphate***	***Silica***
Australian cattle dog				✓		
Bichon frise	✓	✓			✓	✓
Cairn terrier	✓					
Chihuahua	✓					
Cocker spaniel		✓			✓	✓
Dachshund				✓		
Dalmatian			✓			
English bulldog			✓	✓		
German shepherd						✓
Golden retriever						✓
Labrador retriever						✓
Lhasa apso	✓	✓				
Maltese	✓					
Mastiff				✓		
Miniature poodle	✓	✓			✓	
Miniature schnauzer	✓	✓	✓		✓	✓
Newfoundland				✓		
Old English sheepdog						✓
Pomeranian	✓				✓	
Shih tzu	✓	✓	✓		✓	✓
Springer spaniel					✓	
Staffordshire bull terrier				✓		
Yorkshire terrier	✓		✓		✓	

[a]Calculi are most frequently submitted from these breeds. Because of differences in breed popularity, these breeds are not necessarily the ones that are at increased risk for calculus formation.

current cystitis can create overlapping signs of dysuria or stranguria.

Physical Examination Findings

With cystic calculi, the bladder wall may be thickened and the uroliths may be felt by abdominal palpation. Rectal examination may reveal palpable urethral calculi as well as a distended urethra when obstruction is present. Renomegaly and renal pain may occur with ureteral obstruction, or the kidneys may be small and irregular with chronic fibrosis.

Laboratory Testing

The patient's biochemical profile and complete blood count may be normal. In some cases, abnormalities may suggest a certain urolith type, such as an association of

hypercalcemia with calcium oxalate or calcium phosphate uroliths. Azotemia may be present with either upper or lower urinary tract obstruction. In one report,[4] it was unclear whether the presence of nonobstructing nephroliths incited renal failure in cats with chronic kidney disease. Uroliths of both the upper and lower urinary tracts may cause secondary infection. Leukocytosis may be seen with pyelonephritis in some cases but is not associated with simple cystitis.[14]

Urinalysis is an important part of the diagnostic evaluation for all urinary disorders. Crystal solubility is affected by urine pH. Struvite uroliths are more likely to form in alkaline urine; calcium phosphate in alkaline to neutral urine; calcium oxalate and silica in neutral to acidic urine; and urate, xanthine, cystine, and brushite in acidic urine.[15]

In patients without urinary tract disease, calcium oxalate and struvite crystals may form in urine samples that have been refrigerated or analyzed more than 4 to 6 hours after collection, but in patients with uroliths, crystalluria in a fresh urine sample (<60 minutes) may provide clues to urolith composition.

Urolithiasis is frequently associated with urinary tract infection, which may be a primary cause of urolithiasis (i.e., canine struvite uroliths) or secondary to urolithiasis. Urine sediment examination may reveal pyuria or bacteriuria. Urine culture is indicated in all cases of urolithiasis. Infection has been documented in 75% of dogs with cystic calculi when the results of urine, bladder mucosal biopsy, and urolith culture are combined.[16]

Specialized tests may be recommended for specific urolith types (e.g., tests for hyperadrenocorticism in patients with calcium oxalate uroliths).

IMAGING

Not all patients with signs of urinary disease need imaging at first presentation. A female dog with a short duration of pollakiuria and urgency may have a simple bladder infection that will resolve with a short course of antibiotics. For dogs and cats with lower urinary tract signs, imaging is recommended if clinical signs do not resolve rapidly or if signs recur rapidly or frequently and the breed is predisposed to urolithiasis. Because nephrolithiasis and ureterolithiasis are increasingly documented in cats with chronic kidney disease, radiography is recommended for all cats with diagnosed chronic kidney disease.[4–6]

Survey Radiography

Most opacities seen in the urinary bladder on survey radiographs are calculi. Other possibilities include mineralized neoplasia and mucosal wall mineralization.[17] Calcium oxalate and struvite uroliths are generally radiopaque; however, 1.7% to 5.2% of these uroliths are not apparent on survey radiographs. These undetected uroliths are usually small (<1 mm).[18] Urate, cystine, and calcium phosphate calculi are variably radiopaque, and approximately 25% of survey radiographs are interpreted as negative for these uroliths. The incidence of false-negative results with survey radiography is 13% for all urolith types.[18] Urethral calculi are easily overlooked, particularly if the entire urethra is not included in the view. To avoid confusion with the pelvic limbs in male dogs, it may be helpful to pull the pelvic limbs forward to get an unobstructed view of the urethra.

Mineral opacity in the kidneys may be caused by renal calculi, calcification of the renal parenchyma (nephrocalcinosis), calcified tumors, or mineralized cysts. Most mineral opacities in the area of the ureter represent calculi. The end-on view of the deep circumflex iliac artery can be mistaken for a distal ureteral lesion[19] (Figure 1). Nipples and other structures can also be mistaken for uroliths. Lateral and dorsoventral radiographic views should be compared. Small ureteral calculi or those overlying colonic content may be overlooked; the sensitivity of survey radiography for detecting ureteroliths in cats is 81%.[5]

The accuracy of abdominal ultrasonography for detecting uroliths is similar to that of double-contrast cystography.

Contrast Radiography

Pneumocystography (negative-contrast cystography) is more sensitive than survey radiography at detecting calculi, with a false-negative rate of 6.5%.[18] Double-contrast radiography, in which the bladder is distended with gas and contrast medium is instilled (approximately 1 to 3 mL for a cat or small dog and 3 to 5 mL for a large dog), further improves diagnostic accuracy for urolith

Figure 1. The end-on view of iliac vessels ventral to lumbar vertebra 6 (*arrow*) may be mistaken for a ureterolith.

Figure 2. Bilateral antegrade pyelogram. Both renal pelves are moderately dilated.

Left lateral oblique radiograph showing the abrupt termination of the left ureter between lumbar vertebrae 3 and 4.

Right lateral oblique radiograph. The proximal ureter is dilated and tortuous, but contrast is visible throughout the entire ureter.

detection, with a false-negative rate of 4.5%.[18] Excellent descriptions of these techniques have been published elsewhere.[20] For calculi detection, a pool of 200 mg/mL of contrast agent (one part contrast to one part saline) 5 mm deep (about 1 to 5 mL) provides the best accuracy for determining the presence or absence of calculi.[18,21] Although double-contrast radiography is the most sensitive method of counting calculi, an accurate count is obtained in only 53% of cases.[18]

involves ultrasonographic or fluoroscopic guidance to directly inject contrast material into a dilated renal pelvis.[23] Antegrade pyelography may provide a superior image of the renal collecting system and ureters compared with excretory urography[23] (Figure 2). Contrast medium can interfere with urine culture results and artificially increase protein concentration and urine specific gravity. Urinalysis should not be performed within 24 hours after contrast urography.[24]

Most feline nephroliths and ureteroliths contain calcium oxalate.

Excretory urography, also referred to as *intravenous pyelography*, aids in the diagnosis of upper urinary calculi. A description of this technique has also been published elsewhere in the veterinary literature.[19,22] An abrupt termination of contrast within the ureters with lack of distal enhancement and dilation of the renal pelvis and ureter signifies obstructive disease. However, filling defects (lack of contrast) within the renal parenchyma or collecting system can also be seen with cysts, neoplasia, granulomas, abscesses, and hematomas. Antegrade pyelography

Abdominal Ultrasonography

Both radiopaque and nonradiopaque cystic calculi are generally seen with ultrasonography. The interface between the urine and the calculus is intensely hyperechoic (bright white) with acoustic shadows (dark areas) below the calculus (Figure 3). Urethral calculi are difficult to visualize with ultrasound unless they are lodged near the neck of the bladder.

Although ultrasonography is better than survey radiography for detecting uroliths, its false-negative rate of

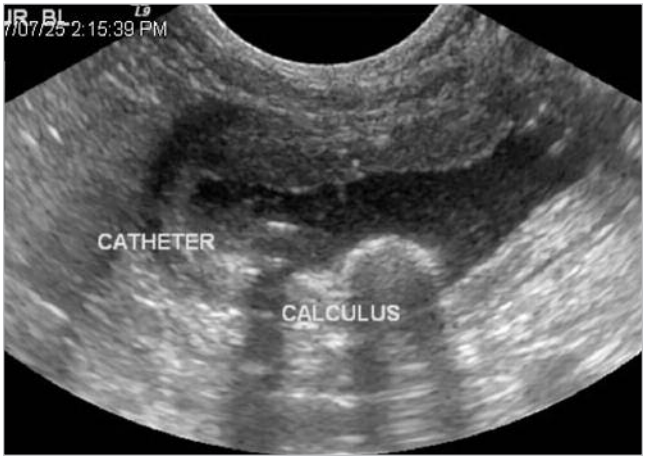

Figure 3. Abdominal sonogram of cystic calculus in urinary bladder. A large, hyperechoic (white) urolith is seen centrally with distal shadowing (dark). The tip of a urinary catheter with distal shadowing is seen in the apex of the bladder.

3.5% is similar to that of double-contrast radiography. Renal calculi are usually visible as intense hyperechoic foci with strong acoustic shadowing. However, visualization may be obscured by overlying bowel gas, and renal calculi may be confused with renal parenchymal calcification or normal shadowing of the collecting system. Pelvic or ureteral dilation makes calculi easier to detect.[25] The sensitivity of ultrasonography for detecting ureteral calculi is 77%, which can be increased to 90% by using a combination of ultrasonography and survey radiography.[5]

Computed Tomography

Uroliths can easily be distinguished from surrounding soft tissue using computed tomography[26] (Figure 4). A recent human study showed that noncontrast computed tomography could be used to predict the composition of uroliths on the basis of differences in radiodensity, measured in Hounsfield units.[26] One in vitro study of uroliths removed from dogs showed the prediction of mineral content to be 75% to 88% accurate for pure uroliths, but mixed uroliths could not be accurately assessed.[26]

UROLITH ANALYSIS

Regardless of removal technique, any urolith that is removed should be submitted for analysis. Quantitative analysis that provides relative percentage composition of each mineral type is preferred over qualitative analysis.

Figure 4. Computed tomography of the abdomen. Radiodense calcium oxalate cystic calculi (*arrow*) in the fluid-filled urinary bladder have a density similar to that of the bone in the vertebral column. The patient is in dorsal recumbency, and the calculi have settled to the dependent portion of the bladder.

CONCLUSION

Urolithiasis is a common disease in dogs and cats, and the lower urinary tract is affected more often than the upper urinary tract. The incidence and type of urolithiasis are influenced by patient sex, breed, age, and diet. Double-contrast cystography is the most accurate method of diagnosis, although survey radiography, ultrasonography, and, potentially, computed tomography are useful diagnostic imaging techniques. Urinalysis contributes to the diagnosis, but chemical analysis of urolith composition is necessary for definitive diagnosis.

REFERENCES

1. Cannon AB, Westropp JL, Ruby AL, Kass PH. Evaluation of trends in urolith composition in cats: 5,230 cases (1985-2004). *JAVMA* 2007;231(4): 570-576.
2. Houston DM, Moore AEP, Favrin MG, Hoff B. Feline urethral plugs and bladder uroliths: a review of 5484 submissions 1998-2003. *Can Vet J* 2003;44:974-977.
3. Lulich JP, Osborne CA. Epidemiological shifts in feline urolith type. Paper presented at: Hill's Symposium on Lower Urinary Tract Disease; 2007; Sunny Isles Beach, FL.
4. Ross SJ, Osborne CA, Lekcharoensuk C, et al. A case-control study of the effects of nephrolithiasis in cats with chronic kidney disease. *JAVMA* 2007; 230(12):1854-1859.
5. Kyles AE, Hardie EM, Wooden BG, et al. Clinical, clinicopathologic, radiographic, and ultrasonographic abnormalities in cats with ureteral calculi: 163 cases (1984-2002). *JAVMA* 2005;226(6):932-936.
6. Lekcharoensuk C, Osborne CA, Lulich JP, et al. Trends in the frequency of calcium oxalate uroliths in the upper urinary tract of cats. *JAAHA* 2005;41: 39-46.
7. Ling GV, Thurmond MC, Choi YK, et al. Changes in proportion of canine urinary calculi composed of calcium oxalate or struvite in specimens analyzed from 1981 through 2001. *J Vet Intern Med* 2003;17(6):817-823.
8. Houston DM, Moore AEP, Favrin MG, Hoff B. Canine urolithiasis: a look at over 16000 urolith submissions to the Canadian Veterinary Urolith Centre from February 1998 to April 2003. *Can Vet J* 2004;45:225-230.
9. Osborne CA, Lulich JP, Polzin DJ, et al. Analysis of 77,000 canine uroliths: perspectives from the Minnesota Urolith Center. *Vet Clin North Am Small Anim Pract* 1999;29(1):17-38.
10. Weichselbaum RC, Feeney DA, Jessen CR, et al. An integrated epidemiologic and radiographic algorithm for canine urocystolith mineral type prediction. *Vet Radiol Ultrasound* 2001;42(4):311-319.
11. Ross SJ, Osborne CA, Lulich JP, et al. Canine and feline nephrolithiasis: epidemiology, detection, and management. *Vet Clin North Am Small Anim Pract* 1999;29(1):231-250.
12. Snyder DM, Steffey MA, Mehler SJ, et al. Diagnosis and surgical management of ureteral calculi in dogs: 16 cases (1990-2003). *N Z Vet J* 2005;53(1): 19-25.
13. Ling GV, Ruby AL, Johnson DL, et al. Renal calculi in dogs and cats: prevalence, mineral type, breed, age, and gender interrelationships (1981-1993). *J Vet Intern Med* 1998;12(1):11-21.
14. Bartges JW. Diagnosis of urinary tract infections. *Vet Clin North Am Small Anim Pract* 2004;34(4):923-933.
15. Adams LG, Syme HM. Canine lower urinary tract diseases. In: Ettinger SJ, Feldman EC, eds. *Textbook of Veterinary Internal Medicine.* Vol 2. 6th ed. St. Louis: Elsevier Saunders; 2005:1850-1874.
16. Gatoria IS, Saini NS, Rai TS, Dwivein PN. Comparison of three techniques for the diagnosis of urinary tract infections in dogs with urolithiasis. *J Small Anim Pract* 2006;47:727-732.
17. Park RD, Wrigley RH. The urinary bladder. In: Thrall DE, ed. *Textbook of Veterinary Diagnostic Radiology*. 5th ed. St. Louis: Saunders Elsevier; 2007:708-724.
18. Weichselbaum RC, Feeney DA, Jessen CR, et al. Urocystolith detection: comparison of survey, contrast radiographic and ultrasonographic techniques in an *in vitro* bladder phantom. *Vet Radiol Ultrasound* 1999;40(4): 386-400.
19. Feeney DA, Johnston GR. The kidneys and ureters. In: Thrall DE, ed. *Textbook of Veterinary Diagnostic Radiology*. 5th ed. St. Louis: Saunders Elsevier; 2007:693-707.
20. Essman S. Contrast cystography. *Clin Tech Small Anim Pract* 2005;20(1):46-51.
21. Feeney DA, Weichselbaum RC, Jessen CR, Osborne CA. Imaging canine urocystoliths: detection and prediction of mineral content. *Vet Clin North Am Small Anim Pract* 1999;29(1):59-72.
22. Heuter KJ. Excretory urography. *Clin Tech Small Anim Pract* 2005;20(1): 39-45.
23. Adin CA, Herrgesell EJ, Nyland TG, et al. Antegrade pyelography for suspected ureteral obstruction in cats: 11 cases (1995-2001). *JAVMA* 2003;222(11): 1576-1581.
24. Feeney DA, Osborne CA, Jessen CR. Effects of radiographic contrast media on results of urinalysis, with emphasis on alteration in specific gravity. *JAVMA* 1980;176:1378-1381.
25. Nyland TG, Mattoon JS, Herrgesell EJ, Wisner ER. Urinary tract. In: Nyland TG, Mattoon JS, eds. *Small Animal Diagnostic Ultrasound*. 2nd ed. Philadelphia: Saunders; 2002:158-195.
26. Pressler BM, Mohammadian LA, Li E, et al. In vitro prediction of canine urolith mineral composition using computed tomographic mean beam attenuation measurements. *Vet Radiol Ultrasound* 2004;45(3):189-197.

ARTICLE #1 CE TEST

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1. Calcium oxalate uroliths are ____ times more likely than struvite uroliths to occur in the bladder of male cats.
a. 0.5 b. 1 c. 1.6 d. 3

2. Calcium oxalate uroliths are ____ times more likely than struvite uroliths to occur in the bladder of male dogs.
a. 0.5 b. 1 c. 1.6 d. 3

3. Struvite uroliths are ____ times more likely than calcium oxalate uroliths to occur in the bladder of female dogs.
a. 0.5 b. 1 c. 3 d. 15

4. Nephroliths and ureteroliths in cats are most often composed of
a. struvite.
b. calcium oxalate.
c. calcium phosphate.
d. urate.

5. Female dalmatians are predisposed to _____ urolithiasis.
a. struvite
b. calcium oxalate
c. calcium phosphate
d. urate

6. What percentage of cats with chronic kidney disease has nephrolithiasis?
a. ~10% b. ~25% c. ~50% d. ~87%

7. Which type of crystal is most likely to precipitate in alkaline urine?
a. struvite
b. calcium oxalate
c. urate
d. cystine

8. Which aspect of urinalysis is affected by delay in analysis?
a. urine specific gravity
b. urine pH
c. crystalluria
d. glucosuria

9. Overall, what percentage of survey radiographs are falsely interpreted as negative for uroliths?
a. 3.5% b. 6.5% c. 13% d. 25%

10. Which of the following factors has the least effect on detection of uroliths on survey radiography?
a. urolith mineral composition
b. urolith size
c. urolith location
d. patient species