Urolithiasis occurs commonly in dogs and cats, and approximately 98% occur in the lower urinary tract. Urolith formation occurs with sustained alterations in urine composition that promotes supersaturation of one or more substances in urine, resulting in precipitation and subsequent organization and growth into uroliths. Approximately 80% of canine uroliths and 90% of feline uroliths are either struvite or calcium oxalate. Calcium oxalate and struvite occur at approximately even frequency, although struvite now occurs more commonly. The third most common type of mineral is urate. Urolith formation is dependent on a combination of many factors, including urine pH, state of saturation (related to concentrations of minerals in urine), inhibitors and promoters of urolith formation, complexors, and macrocrystalline matrix.

**Struvite Urolithiasis**
Infection-induced struvite is the most common form occurring in dogs, whereas sterile struvite is the most common form occurring in cats. However, any animal that develops a bacterial urinary tract infection (UTI) with a urease-producing microorganism can develop infection-induced struvite uroliths. Sterile struvite uroliths have been documented to occur in dogs, but they are very rare.

**Dogs:** Struvite uroliths typically, but not always, form in female dogs (because of their higher risk for development of a bacterial UTI) and in dogs with immunosuppressive diseases or receiving immunosuppressive therapy, because of their increased risk for bacterial UTIs. They can occur at any age, but are more common in young adult dogs.

**Cats:** Sterile struvite is the most common type of struvite urolith occurring in cats. It typically occurs in young adult cats. In older cats (> 10 years) and in kittens (< 1 year), infection-induced struvite urolith formation is more common than formation of sterile struvite uroliths because of the increased risk in these cats for development of a bacterial UTI.

*NOTE:* Crystalluria is not synonymous with urolithiasis. In healthy dogs, more than 50% of urine samples will contain struvite crystals without a bacterial urinary tract infection and without subsequent urolith formation. Likewise, some animals with active stone disease will not have crystals; however, most animals with active struvite stone disease will have crystalluria.

*Diagnostic findings:* Patients with struvite uroliths have alkaluria and often struvite crystalluria. A bacterial UTI (usually with *Staphylococcus* spp., because it produces the enzyme urease) is present with infection-induced struvite; however, a UTI is not present with sterile struvite. Struvite uroliths are radiodense and often large and numerous. Infection-induced struvite uroliths typically form in young to middle-aged adult female dogs, whereas sterile struvite uroliths typically form in young adult male and female cats.

*Treatment:* Struvite uroliths may be removed surgically or through minimally invasive procedures, but are amenable to medical dissolution. Struvite uroliths may be dissolved by inducing an acidic urine pH, increasing urine volume (decreased urine specific gravity), and feeding a diet that is restricted in magnesium and phosphorous. With infection-induced struvite uroliths, an antimicrobial agent must also be administered. The average dissolution time is 8 weeks for infection-induced struvite and 2 to 4 weeks with sterile struvite uroliths. Once uroliths are dissolved radiographically, dissolution therapy should continue for an additional 2 to 4 weeks. An alternative dissolution protocol has been shown to be effective in more than 80% of dogs. In this protocol, the diet is not changed; instead, a urinary acidifier (e.g., d,l-methionine) is administered in combination with an appropriate antibiotic for the organism responsible for struvite formation (typically *Staphylococcus*).

*Prevention:* With infection-induced struvite uroliths, prevention and treatment of UTI will prevent recurrence because it is the UTI that causes these stones to form. With sterile struvite uroliths, prevention involves change of diet to one that is acidifying, induces a diuresis, and is lower in magnesium and phosphorous.

**Urinary Tract Infections**
The urogenital tract is in contact with the external environment and bacteria normally reside in the distal part of the tract. The urinary tract has many defense mechanisms to prevent bacterial urinary tract infection, including anatomic barriers (length of urethra, presence of high pressure zones, peristalsis, vesicoureteral flaps, and extensive renal
blood supply and flow), mucosal defenses (glycosaminoglycan layer, secretory antibody, intrinsic antimicrobial properties, exfoliation of cells, and commensal nonpathogenic bacteria), composition of urine (osmolality, high urea nitrogen concentration, organic salts, low-molecular-weight carbohydrates, and Tamm-Horsfall mucoprotein), cell-mediated and humoral-mediated immunity, and micturition (frequent and complete voiding of urine). For a UTI to occur, there must be one or more temporary or permanent breaks in host defenses and colonization by a uropathogenic organism. For UTI, bacteria must possess one or more urovirulence factors for motility, adherence, invasion, production of enzymes, and production of toxins. Most UTIs originate from the ascension of bacteria from the lower urogenital tract.

**Physical examination findings and clinical signs:** UTIs may be symptomatic or asymptomatic. Bacterial infection of the lower urinary tract is often associated with signs similar to other lower urinary tract (LUT) diseases, including hematuria, pollakuria, dysuria, stranguria, and inappropriate urination. Bacterial infection of the upper urinary tract may be associated with hematuria, but may also be associated with systemic illness. About 2% or 3% of dogs present with a UTI, which is more common in females than in males. Fewer than 1% of cats under 10 years old have a UTI, while more than 40% of cats more than 10 years old have a UTI with signs of LUT disease.

**Diagnosis:** Diagnosis may be made on urinalysis, but urine culture of urine collected by cystocentesis is best. UTI may be associated with pyuria (> 5 WBC/hpf), but not always. Hematuria may or may not be present. Staining the urine sediment with a modified Wright’s stain increases the positive and negative predictive value. Additionally, urine sediment examination may reveal struvite crystalluria or casts. Urine culture is the most definitive means of diagnosing a bacterial UTI. If processing is delayed, refrigerate the sample. Alternatively, a blood agar plate can be streaked and later submitted for identification and antimicrobial susceptibility pattern if bacteria grow. If bacteria grow on initial agar, then organisms are transferred to agar plates, and agar gel antimicrobial diffusion testing is performed to determine the organism’s susceptibility to antimicrobial agents.

**Common isolates:** *Escherichia coli* is the most common bacteria found in dogs and cats with UTIs, accounting for one-half to two-thirds of infections. Gram-positive organisms are the second most common, with *Staphylococci* and *Streptococci* accounting for one-quarter to one-third of infections. Other bacteria accounting for the remaining one-quarter to one-third of infections include *Proteus* spp., *Klebsiella* spp., *Pasteurella* spp., *Enterobacter* spp., *Pseudomonas* spp., *Corynebacterium* spp., and *Mycoplasma* spp.

**Treatment:** Treatment of bacterial urinary tract infection is dependent on whether the breach in host defenses is temporary or persistent. Bacterial urinary tract infections can be classified as simple/uncomplicated, or complicated.

**Simple/uncomplicated bacterial UTI.** A bacterial UTI with no underlying structural, neurologic, or functional abnormality is considered a “simple” infection. This occurs in many dogs. Usually it is successfully treated with a 10- to 14-day course of the proper antimicrobial administered at appropriate dose and frequency. A recent study demonstrated the effectiveness of a 3-day course of once-a-day high-dose enrofloxacin. Clinical signs should resolve and urinalysis results should improve within 2 days.

**Complicated bacterial UTI.** A bacterial UTI associated with a structural, neurologic, or functional abnormality is deemed “complicated.” These can occur in reproductively intact dogs, all cats, and any animal with predisposing causes for bacterial UTIs (e.g., renal failure, hyperadrenocorticism, diabetes mellitus), for example. In addition, this includes animals that have bacterial UTIs that are relapses, reinfections, or superinfections. Pyelonephritis and prostatitis are examples of complicated bacterial UTIs. Complicated infections should be treated for 3 to 6 weeks. Complicating factors for recurrent UTIs include breaks in host defenses or bacterial factors. Breaks in host defenses may be local (e.g., recessed vulva, anatomic defects, indwelling urinary catheter), and breaks in systemic host defenses include complicating diseases (e.g., diabetes mellitus, hyperadrenocorticism, hypothyroidism, hyperthyroidism). Complicating bacterial factors include an unusual organism (e.g., *Corynebacterium*) and multidrug resistance.

**Prevention.** Minimize bacterial contamination of the urinary tract and avoid or minimize conditions that impair host defenses. Catheterization and endoscopy of the urinary tract always carry a risk of inducing a bacterial urinary tract infection.
Resistant Urinary Tract Infections

Resistant *E. coli*. Several options may exist depending on the results of the culture and sensitivity, including fluoroquinolones, aminoglycosides, potentiated beta-lactams, carbaminopenems, third-generation cephalosporins, and cefovecin.

*Saphylococcus* (methicillin resistant). These appear to be more difficult to treat. With resistance to methicillin, beta lactam antibiotics, even potentiated ones, will not be effective. *Staphylococci* are inherently resistant to fluoroquinolones (as are most gram-positive cocci), even with a favorable sensitivity pattern. Treatment may include chloramphenicol, trimethoprim-sulfa, linezolid, and vancomycin.

*Enterococcus*. Oftentimes *Enterococcus* UTI is not associated with clinical signs, and there is a suggestion that not treating may be better than treating. In some animals without clinical signs or urinalysis changes (pyuria, hematuria), no treatment with reculture in 2 weeks may reveal eradication of the organism. Treatment should be considered for animals with active clinical infection or in those that are immunocompromised and may include penicillins with or without amikacin. *Enterococci* are inherently resistant to cephalosporins, fluoroquinolones, trimethoprim-sulfa, and erythromycin, even if favorable sensitivity results.

Prophylactic antimicrobial treatment: This may be indicated in animals with relapses or frequent reinfections.

Antimicrobial agents: Prophylactic antimicrobial therapy may be undertaken with either pulse therapy (agent is administered 1 week out of every 4 weeks) or by administering the agent at one-third to one-half of the dose once a day, typically at night. If a “breakthrough” infection does not occur during a 6-month period, then antimicrobial treatment can usually be discontinued. Disadvantages of this approach include the possible development of resistant bacteria and the side effects of the antimicrobial agent.

*Methenamine*. Methenamine, an effective preventative in select cases, is a cyclic hydrocarbon that is hydrolyzed to formaldehyde at pH < 6.5. It is effective against many organisms, but may cause systemic acidosis because it has acidifying properties.

*Nitrofurantoin*. Nitrofurantoin is a urinary antiseptic that has activity against many organisms. It is not used much in veterinary medicine; therefore, susceptibility is high. However, complications include GI upset, hepatopathy, and peripheral neuropathy.

*Estrogens*. Estrogens may be helpful in female dogs with recurrent vaginocystitis. The dose is same as used with urinary incontinence.

*Urinary acidifiers*. Urinary acidifiers do not work for the prevention of bacterial UTI in dogs and cats.

*Ecotherapeutics*. Ecotherapeutics include probiotics (live bacteria) and probiotics (fiber sources that select for certain strains of bacteria), which may populate the GI tract and thus the distal urogenital tract. There is minimal evidence that this aids in preventing UTIs; however, it does seem to help some dogs.

*Cranberries*. Cranberries contain proanthocyanidins, which bind to adhesins, primarily PapG pili, which are virulent factors involved with the binding of the bacteria to uroepithelial cells. PapG pili are found on 25% to 50% of canine *E. coli*, but not on most other bacteria. Therefore, proanthocyanidins might be helpful in preventing certain strains of *E. coli* from binding to uroepithelia, but not all *E. coli* and not all bacteria. There is evidence in human medicine (nearly two dozen positive randomized, controlled clinical trials), but one study in dogs failed to show benefit; nonetheless, some dogs may benefit from proanthocyanidins found in cranberry extract.

*D-mannose*. D-mannose is a sugar that may prevent bacterial adherence. It is also incorporated into the glycosaminoglycan layer and may prevent bacterial invasion into uroepithelial cells.

**Calcium Oxalate**.
Calcium oxalate accounts for 40% to 50% of all uroliths. Risk factors for calcium oxalate formation included increased urinary and/or oxalate excretion and aciduria.
**Diagnostic findings:** Calcium oxalate uroliths tend to occur in middle-aged or older dogs and cats. Long-haired and ragdoll cats and small-breed and Bichon dogs have an increased incidence. Aciduria is usually present, although calcium oxalate crystalluria is present in fewer than 50% of cases. Hypercalcemia occurs in 20% to 35% of cats (usually idiopathic in origin) and 4% of dogs (usually primary hyperparathyroidism). Hyperadrenocorticism is a risk for calcium oxalate formation in dogs.

**Treatment:** At present, there are no medical dissolution protocols for dogs and cats with calcium oxalate uroliths. If calcium oxalate uroliths are causing clinical signs, then they must be physically removed. Cystotomy is one option for removal.

**Catheter-assisted retrieval.** This technique involves passing a urinary catheter and aspirating stones through the catheter; therefore, uroliths must be small enough to pass through the internal diameter of the lumen of the urethral catheter.

**Voiding urohydropropulsion.** This technique utilizes gravity to assist in expelling the stones. For this technique to be successful, the largest stone must be small enough to pass through the urethra. We are able to retrieve up to 1 cm stones in female dogs, stones of 2 to 3 mm in male dogs, 7 mm stones in female cats, and 1 mm stones in male cats. In this technique, the patient is placed under general anesthesia and a urinary catheter is inserted. The urinary bladder is distended with sterile fluid, and the patient is held upright by support under the axilla. The urinary catheter is removed, and the urinary bladder is palpated through the abdominal wall. The bladder is gently agitated, and then gentle pressure is applied to it so that the micturition reflex is initiated. Urine is caught in a cup or bowl beneath the urethral opening. Voiding urohydropropulsion can be used in combination with other treatment modalities for bladder stone disease.

**Cystoscopy and retrieval and laser lithotripsy.** Cystoscopy can be performed using a rigid cystoscope (in female dogs and cats) or a flexible cystoscope (in male dogs). I perform cystoscopy usually with the patient in dorsal recumbency under general anesthesia. Uroliths can be retrieved using baskets and graspers inserted through the operating channel of the cystoscope. Laser lithotripsy can be used to manage bladder stones using a Ho:YAG laser, which fragments the stone into smaller pieces that can be retrieved.

**Cystoscopic-assisted cystotomy.** Cystoscopic-assisted cystotomy is similar to laparoscopic-assisted cystotomy. A small incision is made on ventral midline over the urinary bladder. In male dogs, the incision is made just cranial to the preputial reflection. The urinary bladder is grasped and brought to the incision edge of the linea, where it is sutured with a continuous pattern of 2-0 or 3-0 Monocryl. A stab incision is made, and a rigid cystoscope is inserted into the urinary bladder. Stones are retrieved using instruments passed through the cystoscope. The urinary bladder is closed with a single layer of 2-0 or 3-0 Monocryl, the linea closed with 2-0 or 3-0 PDS, and the skin and SQ closed with 2-0 or 3-0 Monocryl in a continuous intradermal pattern.

**Prevention:** Calcium oxalate uroliths are recurrent; therefore, preventative measures are warranted. There is an approximate 10% recurrence at 6 months and 35% recurrence at 12 months. The goal of prevention is to lower the amount of calcium oxalate by decreasing the urinary levels of the calcium and the oxalate and by increasing the urine volume in order to dilute the minerals.

**Cats with hypercalcemia.** In cats with calcium oxalate uroliths that have idiopathic hypercalcemia, feed a high-fiber, mineral-restricted diet and administer an alkalinizing agent (potassium citrate).

**Cats without hypercalcemia.** In cats with calcium oxalate uroliths without hypercalcemia, feed a diet that induces a diuresis, that is mineral restricted, and that induces a neutral to alkaline urine pH. There are several feline diets formulated to prevent struvite and calcium oxalate, including Prescription Diet C/D Multicare, Royal Canin S/O, and Purina CNM UR St/Ox.

**Dogs.** In dogs with calcium oxalate uroliths, feed a diet that is mineral restricted, diuresing, and alkalinizing. There are two canine diets available: Prescription Diet U/D and Royal Canin S/O. Alternatively, a higher-fiber diet with supplemental potassium citrate may be used.

**Pharmacologic management.** Oral potassium citrate may be beneficial in managing calcium oxalate uroliths because it is a calcium oxalate inhibitor and because it is alkalinizing in nature. Vitamin B6 increases metabolism of
glyoxylate, a precursor of oxalic acid, to glycine, thereby decreasing urinary oxalate excretion. One study in adult calcium-oxalate-forming dogs showed lower plasma B6 levels when compared with non-urolith-forming dogs. Thiazide diuretics induce diuresis and decrease urinary calcium excretion by increasing absorption from urine. Glucocorticoids have been recommended to decrease blood calcium concentrations in cats with idiopathic hypercalcemia; however, they do so by increasing urinary excretion. Bisphosphonates have been recommended for cats with idiopathic hypercalcemia; however, no studies have been published.

References