Urolithiasis, Struvite (Canine)

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Contributors:
Revised by Kari Rothrock DVM, 2/11/2022
Revised by Kari Rothrock DVM, 6/6/2016
Original authors were Linda Shell DVM, DACVIM (Neurology) and Joe Bartges DVM, PhD, DACVIM, DACVN, 3/15/2010

Synonyms

Bladder stone
Magnesium ammonium phosphate urolithiasis
Urolith

Disease Description

Definition

Urolithiasis refers to one or more stones (uroliths) in the urinary tract. Uroliths can be found in the upper urinary tract (i.e. renal pelvis, ureter) and/or lower urinary tract (i.e. urinary bladder, urethra). Approximately 97% of uroliths occur in the lower urinary tract.[1]

Struvite uroliths are composed of magnesium ammonium phosphate hexahydrate.[2-4] Along with calcium oxalate, struvite uroliths are one of the most common uroliths in dogs and cats.[5-9] Struvite uroliths occur most often in the urinary bladder and urethra, but they can occasionally be found in the upper urinary tract of dogs and less commonly cats.[10]

Etiology and Pathophysiology

Uroliths form with sustained alterations in urine that promote supersaturation of certain substances. Eventually, crystals form, which can grow into an organized stone.[1,2] Sometimes foreign material (e.g. suture material) can serve as scaffolding for crystal precipitation and stone formation.[2] Possible factors involved in urolith formation include urine pH; mineral concentration of urine; inhibitors and promoters of urolith formation; complexors; and macrocrystalline matrix.[1]

Struvite uroliths can be infection-induced or sterile. Infection-induced struvite urolithiasis is the most common form in the dog, whereas sterile struvite urolithiasis is more common in the cat.[1,2,5,10]

Infection-Induced Struvite Uroliths

In the dog, most struvite uroliths are caused by urinary tract infection (UTI) with urease-producing micro-organisms.[1] In contrast, UTI-induced urolithiasis is rare in the cat, encompassing approximately 5% of cases of struvite urolithiasis.[2,4,10,11]

Staphylococcus spp. are the most common causative agents.[1,11-13] Less commonly seen urease-producing bacteria include *Proteus* spp. or *Enterococcus* spp. Rarely *Escherichia coli*, *Pseudomonas* spp., *Klebsiella* spp., *Corynebacterium urealyticum*, or *Ureaplasma/Mycoplasma* spp. induce struvite formation.[1-3,13] One study of dogs with struvite urolithiasis reported that *Staphylococcus* spp. were cultured in 19/23 patients.[13]

Urease cleaves urea, which is abundant in urine, into ammonium and bicarbonate. Ammonium then combines with magnesium and phosphate in urine to form magnesium ammonium phosphate hexahydrate (i.e. struvite) crystals. Leftover bicarbonate raises urine pH, making struvite crystals less soluble. Ammonium damages urothelial glycosaminoglycan coating, allowing struvite crystals and bacteria to attach to urothelium. Attached struvite crystals then aggregate and form uroliths. Bacteria may become trapped within layers of struvite uroliths as they enlarge.[4,12]

Sterile Struvite Uroliths

Sterile struvite urolithiasis is rare in the dog but very common in the cat.[2,11] Cause of sterile struvite urolithiasis is poorly understood. Associated factors include alkaline urine; diets high in magnesium, phosphorus, calcium, and fiber; high levels of magnesium and phosphorus in urine; highly concentrated urine; familial history of struvite urolithiasis; and distal renal tubular acidosis.[4,5]

Diagnosis

Physical Examination Findings/History: Some patients with struvite urolithiasis are asymptomatic. In symptomatic patients, lower urinary tract signs are common, including hematuria, dysuria, pollakiuria, stranguria, and urinary incontinence.[2,5]

Struvite uroliths in the urethra can cause urethral obstruction. Signs and findings associated with urethral obstruction include vomiting, abdominal pain, dehydration, depression, cardiac arrhythmias, bladder distension, bladder rupture with uroabdomen, and collapse.[1,2] Struvite uroliths in the kidney or ureter may be asymptomatic or cause signs/symptoms of kidney pain, hematuria, and/or ureteral obstruction (e.g. vomiting, abdominal pain, stranguria, vocalization).

Urinalysis: Struvite crystalluria is commonly seen with struvite urolithiasis. Struvite crystals exhibit a “coffin lid” appearance (**Figures 1A, 1B**).[1] Note that crystalluria is not an indicator of urolithiasis nor does it increase risk for stone formation.[2] Up to 50% of urine samples from normal dogs contain struvite crystals.[11] Struvite crystals tend to form in alkaline urine, typically in pH >6.5-7.1 They can also form in urine samples as the urine cools below body temperature.[1] Note that some patients with urolithiasis do not have crystalluria.[1] Other possible abnormalities on urinalysis include hematuria, proteinuria, pyuria, and bacteriuria.[2,4,5]

Radiography: Struvite uroliths are moderately to markedly radiopaque (**Figures 2A, 2B**); however, they are typically less radiopaque than calcium oxalate uroliths.[5,10] They can be smooth and round (**Figures 2C, 3**) or faceted.[1] Struvite uroliths are most commonly found in the urinary bladder and urethra. They are rarely in the ureter or renal pelvis.[1,2] Single or multiple stones may be present.[2,10]

Patients with infection-induced struvite urolithiasis tend to have more stones compared to patients with sterile struvite uroliths.[1] Infection-induced struvite uroliths may vary in size and can be quite large. Sterile struvite stones are typically smaller (<5-10 mm).[1] Uroliths <3 mm in diameter are very difficult to detect on survey radiograhs.[5] Failure rate for detection of uroliths on survey radiographs ranges from 2-27%.[4]

Ultrasonography: Abdominal ultrasonography may be helpful in visualizing some uroliths; however, ultrasonography is less helpful in assessing shape and number of uroliths compared to survey radiographs.[10] Bladder wall can also be assessed.

Urolith Mineral Analysis: Quantitative mineral analysis can confirm urolith composition. Some uroliths have mixed composition in which the shell and center are made of different materials.[2] Do not place uroliths in formalin for shipping as this can lead to misdiagnosis of mineral composition.[14]

Culture: Urine culture and sensitivity are recommended. Submit any retrieved uroliths for culture as well, especially if urine culture was negative. In one study, 18% of cases with negative urine culture had positive urolith culture, likely because bacteria can be trapped between urolith layers.[2,15]

Disease Description in This Species

Prevalence

According to various studies, struvite uroliths are currently either the most common urolith isolated from dogs or are a close second to calcium oxalate uroliths.[6,8,9,16-18] Struvite uroliths accounted for 53.4% of canine uroliths submitted over a 19-year period in a report from the USA.[16] Struvite uroliths accounted for 43% in a study from the UK and 32.9% in a study from Spain and Portugal.[19,20] One study from Canada reported that 35.8% of all uroliths submitted from 1998-2014 were struvite uroliths.[9] In a report from the Netherlands, struvite uroliths made up 40.9% of all submissions.[6] Struvite uroliths accounted for 41% of all uroliths submitted from dogs to the Minnesota Urolith Center in 2007.[1] Note that over time, incidence of canine struvite urolith submissions have declined, while calcium oxalate submissions have increased.[16,17,20,21] Struvite uroliths accounted for approximately 75% of canine submissions in 1985.[16]

Signalment

Single struvite uroliths are most commonly diagnosed in young, adult dogs. They are the most common type of urolith diagnosed in dogs <1 year of age.[1] Struvite uroliths are more likely to form in female dogs than males. Approximately 71-85% of struvite uroliths submitted are from females.[1,3,6,8,9,22] Small and toy breeds are more likely to be affected than large breed dogs.[9] Breed predispositions include the cocker spaniel, miniature poodle, miniature schnauzer, shih tzu, lhasa apso, Pekingese, dachshund, and bichon frise.[3,22] Some studies have also reported increased prevalence in the golden retriever, Labrador retriever, Bernese mountain dog, Saint Bernard, and rottweiler.[6,9]

Clinical Signs

Some patients with struvite urolithiasis are asymptomatic. Hematuria, pollakiuria, stranguria, urinary incontinence, dysuria, vomiting, fever, dehydration, lethargy, depression, abdominal pain, vocalization, and/or collapse may be noted.[1-4]

Etiology

Corynebacterium spp.
Diet
Enterococcus spp.
Escherichia coli
Genetic, hereditary
Infection
Klebsiella spp.
Mycoplasma spp.
Proteus spp.
Pseudomonas spp.
Staphylococcus spp.
Ureaplasma spp.
Urinary tract infection

Breed Predilection

American cocker spaniel
Bernese Mountain dog
Bichon frise
Dachshund
Golden retriever
Lhasa apso
Miniature poodle
Miniature schnauzer
Pekingese
Poodle
Rottweiler
Saint Bernard
Shih tzu

Sex Predilection

Female

Age Predilection

Young adult

Clinical Findings

Abdominal pain
AFEBRILE
Anorexia, hyporexia
Collapse of patient or syncope
Depression, lethargy
DYSURIA, STRANGURIA
FEVER

Hematuria
HEMORRHAGE
Nausea
PAIN
Pollakiuria
Polydipsia
Polyuria
Urinary bladder distension
Urinary bladder painful
Urinary bladder thickened
Urinary incontinence
Urinary stream disruption
Urination inappropriate
Urine discolored, cloudy
Urine odor unusual or foul smelling
Vocalization increased
VOMITING
Weight loss
ZZZ INDEX ZZZ

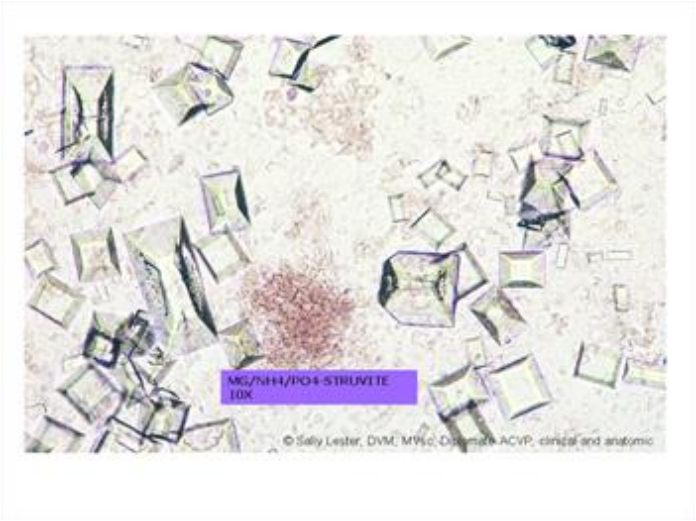
Diagnostic Procedures

Diagnostic Procedures:	Diagnostic Results:
Urinalysis	Bacteriuria, urine bacteria increased CRYSTALLURIA, URINE CRYSTALS INCREASED Proteinuria, albuminuria Pyuria, increased white blood cells Red blood cells present in urine Urine alkaline, pH increased
Radiography of abdomen	Bladder (cystic) urolith Nephrolithiasis Renal or bladder lithiasis Ureteral urolith Urethral urolith
Serum biochemistries	Azotemia/uremia Blood urea nitrogen (BUN) increased Creatinine increased
Ultrasonography of abdomen	Urethral opacity observed
Culture of urine	Aerobic culture may be positive for pathogen
Radiography, contrast procedure	Urethral obstruction
Urolith analysis	Struvite urolith (magnesium ammonium phosphate)

Images

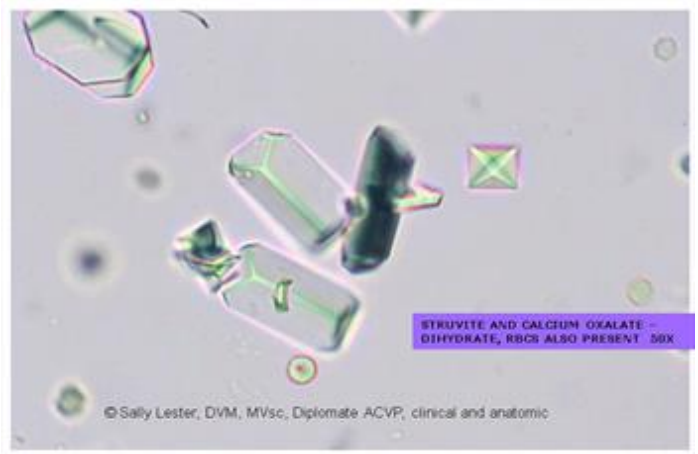
Click on each image to see a larger view

Figure 1A. Struvite crystals



Urine, 10x. Courtesy Dr. Sally Lester

Figure 1B. Struvite & calcium oxalate crystals



Urine, 50x. Courtesy Dr. Sally Lester.

Figure 2A. Struvite stones - preop Lat Xray

Click here to see board discussion

Figure 2B. Struvite stones - preop VD Xray

Click here to see board discussion

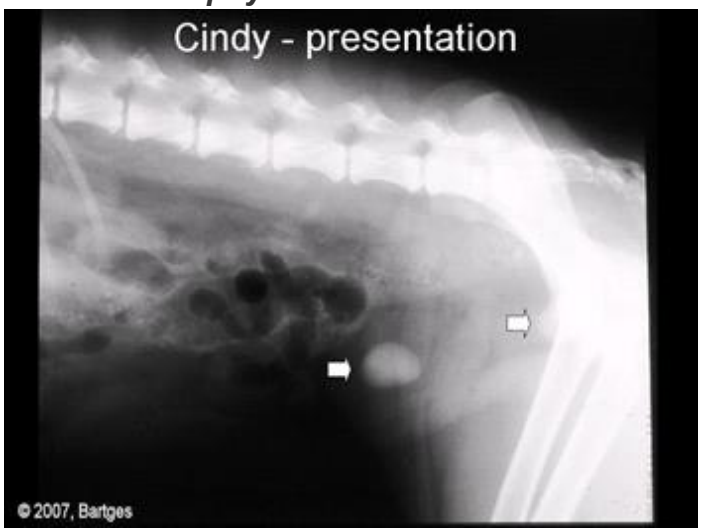
Figure 2C. Struvite stones

Click here to see board discussion

Figure 3. Struvite stones

Struvite stones surgically removed from Korey's bladder. Composition of these stones was determined by complete quantitative calculus analysis.

Figure 4A. Struvite cystolith caused by Staphylococcus infection



This large radiodense stone is presumptively diagnosed as struvite because the dog had a urinary tract infection, alkaluria, and struvite crystals.

Figure 4B. After 2 months of antibiotics and s/d diet

In addition to the absence of stone, the dog's urine pH was acidic, there was no inflammation or crystals, and a urine culture was negative.

Treatment / Management

SPECIFIC THERAPY

Goal of therapy is to eliminate existing uroliths and treat concurrent UTI. Prevent recurrence of struvite uroliths if possible.[1] Remember that crystalluria alone is not an indicator of impending urolithiasis and does not necessarily warrant treatment without presence or history of uroliths.[2]

Medical Dissolution

Struvite stones are amenable to medical dissolution (**Figures 4A, 4B**) by combining antimicrobial therapy and calculolytic diet therapy. Note that for patients with large stones or those at risk for urinary tract obstruction, physical removal may be necessary.[1-4,13,23]

Antimicrobial Therapy: Antimicrobials are essential for treating infection-induced struvite uroliths.[2,11] See the Canine VINcyclopedia chapter on Bacterial Cystitis for additional treatment information. Base therapy on urine culture and sensitivity results. Note that antibiotics must be administered for the duration of medical dissolution. As the outer layers of struvite uroliths dissolve, bacteria that were trapped within the stone are released. Failure to administer antibiotics for sufficient length may result in treatment failure.[1,2,11,24] Administration is typically needed for one month beyond radiographic/ultrasonographic evidence of urolith dissolution.[2]

Calculolytic Diet Therapy: Calculolytic diets are formulated to dissolve struvite uroliths. Key components include reduced magnesium and phosphorus; urine acidifiers; decreased protein (i.e. to reduce sources of urea); and diuresis promotion.[1,11,23-25] Potassium chloride salt is commonly added to dilute urine and decrease crystallization.[26] Addition of sodium chloride also decreases relative super saturation (i.e. measure of solubility of urinary crystalline salt and risk for crystal formation) of struvite.[2,25]

Calculolytic Diet Options: Canine diets available for struvite dissolution include Hill's Prescription Diet s/d™, Purina Pro Plan Veterinary Diets UR Urinary St/Ox™, and Royal Canin® Veterinary Diet Urinary SO.[4,24] Hill's s/d is not intended for long-term maintenance nutrition. It must be used cautiously in young patients (i.e. because of reduced protein); in patients with hypertension and cardiac disease (i.e. because of increased sodium content); and in patients with history of pancreatitis (i.e. because of increased lipid content).[24] Decreased BUN and albumin as well as increased ALP can occur in patients receiving Hill's s/d.[4,24]

Length of Therapy: Dissolution diets are needed for 2-4 weeks beyond dissolution.[1] Infection-induced struvite uroliths may be dissolved with antibiotic therapy alone; however, the process takes longer and is less successful than when combining diet and antibiotic therapy.[1] Average time for

dissolution of infection-induced struvite uroliths using combination therapy is approximately 8 weeks to 3 months.[1,2] One study of struvite uroliths in dogs reported a median of 35 days for full dissolution (range 13-167 days).[13] Sterile uroliths reportedly dissolve faster, with an average dissolution time of 2-4 weeks.[1] Larger uroliths take longer to dissolve because of reduced surface area. Lower urinary tract signs typically improve within 10 days after start of therapy, most likely from treatment of UTIs.[1,4,24]

Alternative Dissolution Protocol: An alternative protocol for dissolving infection-induced struvite uroliths involves administration of antimicrobials and urinary acidifier D,L-methionine. Dietary therapy is not used. In 8/11 dogs administered appropriate antibiotics and D,L-methionine (100 mg/kg PO q 12 hrs), uroliths dissolved in a median of 2 months. The 3/11 dogs with uroliths that failed to dissolve were removed surgically and found to contain calcium oxalate.[27]

Physical Urolith Removal
Physical removal of struvite uroliths is necessary for urinary obstruction (i.e. of renal pelvis, ureter, or urethra); when medical dissolution therapy fails; and for unacceptable clinical signs associated with urolithiasis.[1,2,24]

Voiding Urohydropropulsion (VH): VH can remove small uroliths by inducing voiding and encouraging passage of uroliths through the urethra with voided urine. VH does not work for patients with urethral obstruction.[1] Sedation or anesthesia is recommended. Distend the urinary bladder with sterile saline via cystoscopy or urethral catheterization. Position patient vertically so that the spine is 25° caudal to a line perpendicular to the effects of gravity. Larger dogs may need to be placed in dorsal recumbency on a tilted table.[1] Agitate the bladder to allow uroliths to fall and settle into the bladder trigone, then express the bladder to promote voidance of uroliths. Repeat process until no uroliths are noted on imaging (e.g. cystoscopy, ultrasonography, radiography).[3,24] VH works best for uroliths <5 mm in dogs weighing >8 kg.[2,24] However, successful retrieval of larger stones in smaller patients is reported, including a 10 mm stone from a 7.4 kg dog.[1]

Cystoscopic Retrieval: Removal of small uroliths or urolith fragments can be performed cystoscopically. Urolith basket can be used to snare uroliths that are smaller than the diameter of distended urethra.[1,24]

Laser Lithotripsy: Laser lithotripsy involves placing a Holmium:YAG laser in direct contact with uroliths via cystoscopy to fragment them. Fragmented pieces are removed through cystoscopy or VH. Laser lithotripsy has a reported success rate of 83-100% for female dogs and 68-81% for male dogs.[3,24] Some male dogs are too small for laser lithotripsy to be successful. Furthermore, some large uroliths may be difficult to fragment into pieces small enough for removal.[24]

Extracorporeal Shock Wave Lithotripsy (ESWL): ESWL involves fragmenting uroliths via shock waves generated outside the body. Wet lithotripter requires patient be partially submerged in a water bath. Dry lithotripter generates shock waves through a water-filled cushion.[10] ESWL can be used to fragment cystic calculi; however, it is best suited for treating immobile uroliths (e.g. nephroliths, ureteroliths).[1] Cystic calculi tend to move away from the focal spot of the lithotripter.

Retrograde Urohydropropulsion (RU): RU involves flushing uroliths from the urethra into the urinary bladder. RU does not remove uroliths but rather relocates them to the bladder where they can be removed through cystotomy or medical dissolution. Anesthesia is typically required. If overly distended, the urinary bladder must first be emptied using gentle, decompressive cystocentesis. This lowers urethral pressure, allowing for retrograde movement of uroliths. Place urinary catheter in the distal urethra and flush sterile saline (5 mL/kg or 60 mL, whichever is less) into the urethra. Using concurrent rectal palpation, occlude the urethra. When urethral compression is released, the uroliths should flow into the bladder.[3,24] For a more detailed description of urethral catheterization, see the Canine VINcyclopedia chapter on Urethral Obstruction.

Surgical Removal: Stone removal via cystotomy, ureterotomy, or urethrotomy may be considered.[24] Complications associated with ureterotomy or urethrotomy include stricture formation, hemorrhage, urinary leakage, and surgical dehiscence. Complications from cystotomy (e.g. dehiscence) are uncommon. Urethrotomy is most often performed for stones lodged in the distal urethra (i.e. just anterior to os penis) that cannot be dislodged via RU. Surgery has fallen out of favor for ureteral

stones that cause ureteral obstruction. Ureteral stents or subcutaneous ureteral bypass is used more frequently.[28] For further information on ureteral obstruction therapy, please refer to the Canine VINcyclopedia chapter on Ureteral Obstruction.

SUPPORTIVE THERAPY

Institute additional measures as needed in patients with urethral or ureteral obstruction and more severe clinical signs.

MONITORING

During medical dissolution, evaluate urinalysis 5-7 days after initiating antimicrobial therapy, then every 4 weeks until dissolution is complete. On urinalysis, urine pH should be <7.0 and crystalluria should resolve.[2]

Recheck abdominal radiographs every 4 weeks to ensure uroliths are decreasing in size and/or number. Typically, uroliths decrease in size and/or number by about 50% within the first 4 weeks of therapy.[1] Failure to see improvement in this timeframe could indicate that either the uroliths are not struvite or the owner is non-compliant.[2] Continue medical dissolution therapy for at least 2-4 weeks beyond radiographic evidence of dissolution to ensure that all stones dissolve.[1,11,24]

After infection-induced struvite uroliths are medically dissolved or mechanically removed, recheck urine culture 5-7 days after completion of antimicrobial therapy and again 3-4 weeks later.

PROGNOSIS

Medical dissolution therapy may fail with inadequate treatment of UTIs; uroliths of mixed or non-struvite stone composition; and poor owner compliance.[2,24] Medical dissolution of infection-induced struvite stones is more successful if both antibiotics and dissolution diet therapy are performed simultaneously.[1] In one study of 50 dogs with struvite urolithiasis, 58% had full dissolution of stones; 7 dogs had partial dissolution; 7 dogs had no dissolution; and 7 had an undetermined outcome. Dissolution was more likely in dogs receiving antimicrobial therapy. Maximum urolith diameter; number of uroliths; and baseline urine pH did not affect success.[13] Another small study of 10 dogs receiving therapeutic urinary diet and antibiotics reported that 5 had complete dissolution at a median of 31 days. In the remaining 5 dogs, surgical removal was necessary. In this study, 2/10 dogs could not be cured of urolithiasis, but at least one dog had questionable owner compliance.[23]

Preventive Measures

Prevention of infection-induced struvite urolithiasis is aimed at preventing recurrent UTIs.[28] Dietary therapy is unlikely to be beneficial long term.[1,3,11]

Long term dietary therapy may be beneficial in preventing sterile struvite uroliths. Struvite-prevention prescription diets are typically lower in protein, phosphorus, and magnesium. They also aim to keep urine at an acidic pH and promote diuresis.[1] Options include Royal Canin® Veterinary Diet Urinary SO, Hill's Prescription Diet c/d™, Hill's Prescription Diet w/d™, and Purina Pro Plan Veterinary Diets UR Urinary St/Ox™.[3-5,22] Encouraging water consumption (e.g. feeding canned diet, adding water to dry food) is also beneficial.[3]

Special Considerations

Other Resources

Recent Message Boards discussions on struvite urolithiasis
Recent Message Boards discussions on recurrent struvites
Recent Message Boards discussions on struvite prevention
Recent Proceedings on struvite urolithiasis

Case studies:
Struvite Stone Prevention and Dissolution
How Many Stones?

Common Small Animal Diagnoses algorithm on Hematuria
VIN Library Uro-Nephrology Center: Common Pitfalls in the Diagnosis and Management of Urolithiasis in Dogs and Cats
VIN Library: Diagnosing Cystic Calculi with Ultrasound

Small Animal Radiology and Ultrasonography chapter on Density Changes
Medical FAQ on UTIs
VIN Veterinary Drug Handbook monograph on D,L-Methionine

2016 ACVIM Small Animal Consensus Recommendations on the Treatment and Prevention of Uroliths in Dogs and Cats
Minnesota Urolith Center: Canine Struvite Risk Management
Minnesota Urolith Center: Canine Struvite Medical Dissolution

Rounds:
Nutritional Management of Lower Urinary Disease
Renal Failure in the Endocrine Patient
Rational Approach to Antimicrobial Therapy

Veterinary Partner articles:
Struvite Bladder Stones in Dogs
Cystotomy for Bladder Stones
Lithotripsy in Dogs and Cats

VIN Mentor Visual Procedures Manual Video on Cystotomy

For more images, see the Cystic Calculi, Struvite, Cystic Calculi, Gross Images, Cystic Calculi Radiographs, Cystic Calculi Ultrasounds, and Urine Sediment with Crystals slideshows in the Image Library

Differential Diagnosis

Cystitis:
Bacterial cystitis
Fungal cystitis
Mycoplasmal cystitis

Other Types of Urinary Tract Disease:
Urethritis
Urinary bladder and urethral neoplasia
Urinary tract trauma

Other Types of Uroliths:
Ammonium urate
Calcium oxalate
Calcium phosphate
Cystine
Dried, solidified blood
Silica
Xanthine

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