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Microbial Infections of Pet Animals Urinary Tract: Review Article

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Abstract

Microbial urinary tract infections (UTIs) are reported to be between the second and third most common reasons for antimicrobial use in pet animals, dogs and cats, representing 12% of all antibiotic prescriptions. UTI refers to microbial colonization of any portion of the urinary system that is normally sterile. The distal urethra is not sterile; it has a normal flora. UTIs are often caused by bacterial organisms that are part of the microflora of the intestinal tract. UTI is usually caused by one single bacterial species. Predominant bacterial species were Gram-ve bacteria, as *Escherichia coli* constituted the major isolated species (about 40-50%), followed by *Proteus* spp., *Pseudomonas aureogenosa, Klebsiella* spp., and *Enterobacter* spp. Gram-positive bacteria such as *Staphylococcus* spp., *Enterococcus* spp., and *Streptococcus* spp., *Leptospira* and *Mycoplasma* spp. Additionally, fungal and viral causes play a reside role to some extent in UTIs. Diagnosis of UTIs in pets is based on clinical signs, urine analysis, and bacterial culture results obtained from urine samples collected, preferably using cystocentesis. The empiric antimicrobial treatments are often administered in the presence of clinical signs as they affect a broad spectrum of bacterial etiology associated with UTIs. Antimicrobial therapy is indicated in most cases while awaiting culture and susceptibility results to overcome the condition. Multidrug-resistant bacteria are an alarming development with significant public and pet health ramifications. Natural alternative methods can be useful as supplemental therapy choices and are much required. Cranberry is frequently used to prevent UTIs in older male dogs, but more research is needed. Prophylactic antibiotic medication, particularly for non-neutered male dogs, has not yet been shown to be significant; however, it may be of help in some cases. This work aimed to supply the researchers and veterinarians with a wider point of view about urinary tract infections in pet animals.

Keywords: Pet animals, Urinary tract infections, UTIs, Companian animals, Diagnosis, Treatment and follow up.

INTRODUCTION

Urinary tract infections (UTIs) are a common concern in pet animal practice as sequelae of compromised host defense mechanisms and a virulent microbe adhere, multiply, and persist in a portion of the urinary tract. The prevalence of UTIs in the dog over its lifetime has been reported to be 14%, and in cats, it has been reported to be between 3% to 19% (Pereira *et al*., 2024).

There are numerous factors thought to impact the risk of UTI in species, comprising sex, age, comorbidities, and functional abnormalities of the urinary tract. Host defenses include normal micturition, anatomic structures, the mucosal barrier, properties of urine, and systemic immunocompetence. (Amphaiphan *et al*., 2021).

UTIs may involve more than one anatomic location, and the infection should be categorized as upper urinary tract (kidneys and ureters) versus lower urinary tract (bladder and urethra). Most bacterial UTIs occur as a consequence of ascending migration of

pathogens through the genital tract and urethra to the bladder, ureters, and one or both kidneys (Tigabie *et al*., 2025).

Frequently, UTIs are induced by bacteria, fungi and viruses. Most of the UTIs in dogs and cats (~75%) involve a sole agent, 20% two co-infecting species, and approximately 5% are caused by 3 mixed species, with *Escherichia coli* (*E. coli*)being responsible for up to half of the infections in dogs. This Gram -ve organisms are also the most common pathogen in cats (60%), with *Staphylococcus felis* (*S. felis*)being the most common Gram +ve in that species, followed by 20% of other Gram-positive cocci, in addition to *Leptospira* spp. (Deprey *et al*., 2021) and *Mycoplasma* spp. (Alves *et al*., 2023). Fungal UTIs is uncommon and occurs usually because of temporary or permanent breaches in immunity of the lower UTIs. *Candida albicans* is the most commonly followed by *Candida glabrata* and *Candida tropicalis*. Also, other fungi may include as *Aspergillus* spp., *Blastomysis* spp., and *Cryptococcus* spp. (Reagan *et al*., 2019; Sender *et al*., 2024). Viral-induced diseases in pets are increasingly determined, particularly of the upper urinary tract, as canine adenovirus type I, herpesvirus, as well as feline coronavirus and leukemia virus (Kruger *et al*., 2011). A better understanding of the defense mechanisms of the urinary tract, the behavior of uropathogenic bacteria, and a rising awareness of the dangers of antimicrobial resistance have led to alterations in the recommendations for diagnosis and treatment of UTI in dogs and cats (Grant *et al*., 2021). So the emergence of multidrug-resistant bacteria (MDR) isolates resistant to three or more antimicrobial categories' implemented in UTI in dogs and cats creates questions about the role of companion animals as potential reservoirs of resistant bacteria and has been reported as a serious public health problem (Smoglica *et al*., 2022).

Given these challenges, there is a critical need to explore alternative treatments that can effectively combat MDR urinary pathogens. These types of treatments are receiving increasing attention in the treatment of UTIs, especially uncomplicated clinical conditions (Biasibetti *et al*., 2019).

The current article aimed to discusse the microbial urinary tract infections in pet animals; their types, the risk factors for complicated conditions, the major associated species, the standards for diagnosis, and different antimicrobial and non-antimicrobial remedy approaches. The zoonotic risks and public health implications associated with MDR UTIs in dogs and cats are addressed.

TYPES OF UTI IN DOGS AND CATS

UTIs in pets can be either: i) Simple or uncomplicated (sporadic cystitis): No predisposing factors or other diseases present; ii) Complicated or recurrent: Seen in pets with underlying medical conditions or predisposing causes; pets with more than three UTIs in the past 12 months (Smee *et al*., 2013). The 2019, International Society for Companion Animal Infectious Diseases revised the classifications of UTI. The revised classification has 3 diagnoses: subclinical bacteriuria, sporadic cystitis, and recurrent UTI (RUTI) (Weese *et al*., 2019).

Predisposing or risk factors for different types of UTIs were correlated very often to several urinary disorders; with the occurrence and the development of urinary bladder stones, insufficient protection of the urogenital tract against external influences due to immunosuppressive therapy (e.g. hyperadrenocorticism and diabetes mellitus) are important risk factors contributing to UTIs in pets. From the anatomical point of view, it is necessary to mention that the urethra in the females of dogs and cats is shorter and wider in comparison to males and this is the reason why urethritis develops more often in females than in males. UTIs are more common in older female dogs (>7 years) (Kocúreková *et al*., 2021).

The significant association of breeds with the presence of UTIs was reported, where Golden Retrievers were found to be more likely to be positive for *E. coli*/*K. pneumoniae* than other pure breeds or mixed breeds, according to a statistical analysis. (Facchin *et al*., 2025).

2. BACTERIAL CAUSES OF UTIS IN DOGS AND CATS

Bacterial urinary tract infections are one of the more common infections in dogs. Approximately 14% of the canine population afflicted by a UTIs. Although they often affect older female canines (>7 years) **(Hernando *et al*., 2021)**.

2.1. *Escherichia coli*

E. coli is the most frequently isolated pathogen, with a prevalence ranging from 35% to 64%, fundamentally, most UTIs are caused by what is termed "extraintestinal pathogenic *E.* coli" (ExPEC) which are belong to phylogenetic group B2 (generally containing more virulence factors or genes) and to a lesser extent group D. These groups of organisms are phylogenetically distinct from commensal and intestinal *E. coli*, which predominantly belong to groups A and B1 (Govindarajan *et al*., 2024).

Specific uropathogenic characteristics and virulence factors (VFs) are required for bacterial strains to initiate an infection, regardless of the presence of a competitive colonization advantage in the gut. VFs of importance to uropathogenic *E. coli* (UPEC) include capsular factors, cytotoxins, invasion factors, siderophores and related transport systems, as well as adhesins that mediate binding to the renal tubule (P, S and F1C fimbriae) and bladder urothelium (Type I fimbriae). This is likely to be of particular importance in dogs with intact urinary tract defense mechanisms (Fig. 1). However, phylogenetic group A and B1 *E. coli*, whilst generally possessing fewer VFs than group B2 and D *E. coli*, may also initiate UTI in dogs if host defenses are compromised (Halaji *et al*., 2022).

E. coli that colonize the urinary tract can protect themselves from the harsh bladder environment by forming biofilms. These biofilms promote persistence leads to chronic and recurrent UTIs (Ballash *et al*., 2022). *E. coli* are assumed a global threat because of the lowering options for antimicrobial therapy. Pets could be a reservoir of multidrug resistanate (MDR) *E. coli*, and the households owning pets had increased (Teng *et al*., 2023).

In a recent Italian study, urine samples collected from 133 dogs manifested at least one of UTI clinical signs and admitted to the Veterinary Teaching Hospital of Milan. Out of these, 28 *E. coli* strains were found, with 60. 7% producing biofilms, 25% being multidrug-resistant, and 3. 6% harboring ESBL (Facchin *et al*., 2025). An investigation study across 12 European countries supported *E. coli* as the most frequently isolated bacterium in dogs; 46.9% and 61.2% in cats (Temmerman *et al*., 2024). The incidence of *E. coli* was 45.58% in study included 2,583 urine samples from dogs suspected of UTIs with high prevalence of resistance to ampicillin (31.42%) (Yudhanto *et al*., 2022). Hernando *et al*., (2021) determined *E. coli* in UTI dogs as (1333/2942; 45.3%) in Spanish survey. While, Punia *et al*., (2018) reported less incidence of *E. coli*; (29.62%) in urine samples collected from 35 dogs suspected of UTI, in India. In Egypt, Hakim *et al*., (2024a) determined 34 and 8 *E. coli* isolates out of 81canine (41.97%) and 38 feline (21.05%) urine samples with notable resistance against imipenem and loading of *bla*NDM-1gene was responsible for resistance against carbapenems. Farag *et al*., (2024) mentioned that *E. coli* was the most common pathogen isolated from 146 dogs (46.4 %) and 162 cats (66.7 %) suffered from lower urinary tract disorders.

2.2. *Leptospira* spp.

Leptospirosis is caused by pathogenic spirochetes of the genus *Leptospira,* which colonize the renal tubules where they reproduce before being excreted via urine. Contaminated water with infected urine is the source of leptospirosis infection, where

Leptospira can enter the bodies of mammalian hosts via lacerations in the skin, contact with mucosa, conjunctiva, and inhalation of aerosols as shown in figure (1). Dogs may have an asymptomatic form or may suffer from a wide range of clinical manifestations, including hepatic, renal failure and severe pulmonary hemorrhage (Schuller *et al*., 2015). Formerly, it was thought that domestic cats were resistant to leptospirosis infection. However, published reports on feline leptospirosis concluded that cats are exposed to Leptospira and may play a role in the epidemiology of the disease (Palerme *et al*., 2019). A study investigated *Leptospira* spp. prevalence in 112 cats from southern Italy, the data revealed detection of 6 serovars in 15.3% (17/112) of tested cats so can represent an additional reservoir or sentinel for a risk of infection (Donato *et al*., 2022).

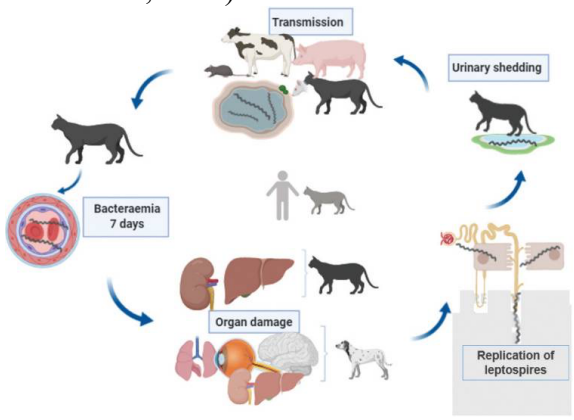


Figure (1) Proposed pathogenesis of leptospirosis in cats and dogs. Replication of leptospires occurs in the kidney leading to urinary bacterial shedding (Murillo *et al*., 2020).

A cross-sectional study in Reunion Island determined cats as a part of the maintenance community of different strains of *Leptospira* spp. The prevalence of *Leptospira* infection in 92 samples of stray and domestic cats has been studied using serological and molecular detection. The results revealed a seroprevalence of 37.0% (34/92) (cut-off 1:40), while using PCR; 28.6% (12/42) of stray cats were tested positive and Leptospiral DNA was detected in renal tissue, urine and blood. The study confirmed that renal carriage and urinary shedding are possible, especially in stray cats which can be considered potential actors within the maintenance community of *Leptospira* in Reunion Island (Holzapfel *et al*., 2021). Also, a longitudinal study was performed using a multidisciplinary approach for the identification of chronically infected stray and sheltered dog populations in São Paulo, Brazil. A total of 123 dogs from three populations were included. Asymptomatic *L. santarosai* infection was observed in all populations studied, suggesting a possible role of dogs in the chain of transmission of this leptospiral species (Miotto *et al*., 2018). Another study of pet leptospirosis detection in Algeria, was conducted in the urines of stray dogs and cats. The results revealed that 5/104 (4.8%) canine urine samples (asymptomatic mixed-breed dogs) were positive while all of the 107 cat urine samples were negative. The confirmed *L. interrogans* prevalence was significantly higher in dogs aged < one year (16.46% - 29.41%) than in adults (Zaidi *et al*., 2018). On the other hand, Delaude *et al*. (2017) stated that in spite of human leptospirosis remains rare in Switzerland, the incidence of canine leptospirosis is unusually high compared to other European countries.

Leptospirosis pulmonary hemorrhage syndrome (LPHS) in dogs and cats has poor prognosis due to acute respiratory failure and dyspnea, leading to death. Cats with mild clinical signs respond well to antimicrobial therapy, while those with chronic leptospirosis developed permanent renal damage (Murillo *et al*., 2020).

2.3. *Mycoplasma* spp.

Mycoplasmas are considered to be part of the normal microbial flora of canine mucosal membranes. However, some of these mycoplasmas may causes UTI by ascending migration from the lower urinary or genital tract. Hemmatzadeh (2019) reported the first report of detection of *Ureaplasma canigenitalium* in an English Cocker Spaniel dog with the history of UTIs and chronic renal insufficiency in Australia. *Mycoplasma canis* was isolated from four of 100 (4%) urine samples obtained by cystocentesis from 100 dogs with symptoms of lower urinary tract disease. Also, Mycoplasmas identified as *M. canis* were isolated from nine dogs with clinical signs of urogenital disease in Norway over 20 months (L'Abée-Lund *et al*., 2003).

2.4. Other Bacterial Species

In Italy, urine samples collected from 133 dogs at Veterinary Teaching Hospital of Milan showed positive microbiological culture of *K. pneumoniae* isolates, (4.51%) (Facchin *et al*., 2025).

European survey determined the causative bacteria of canine UTIs next to *E. coli*; *Staphylococcus intermedius* and *Proteus mirabilis* (13.1%). The frequent Gram +ve isolates were *Streptococcus* spp. (8.3%), *Enterococcus* spp. (8.0%) and *S. aureus* was (0.9%). Gram-negative bacteria included *Klebsiella* spp. (4.0%), *Pseudomonas aeruginosa* (3.6%) and finally *Pasteurella* spp. In second period (0.5%). On the other hand, among examined feline urine samples, coagulase-negative *Staphylococci* were the second-most frequently isolated species (13.2%), including the specific pathogen *Staphylococcus felis*. *Enterococcus* spp. was (17.7%) and *S. aureus* (4.2%). The other Gram-negative pathogens; *Proteus* spp., *Pseudomonas* spp., *Klebsiella* spp., and *Pasteurella* spp. were 5.3%, 4.2%, 1.6% and 1.6%, respectively (Temmerman *et al*., 2024).

A study aimed to bring new insights into the current bacterial urinary tract infections in companion animals scenario of Portugal showed 5306/17472 (30.4%) +ve bacterial culture. Of the culture-positive samples, 5224 (96.6%) were pure cultures and 82 (3.2%) had mixed growth. Other *E. coli* bacteria were *Proteus mirabilis* (11%), *Enterococcus faecium* (5.2%) and *Staphylococcus pseudintermedius* (4.3%), as shown in Figure (2) **(Garcês, *et al*., 2022)**.

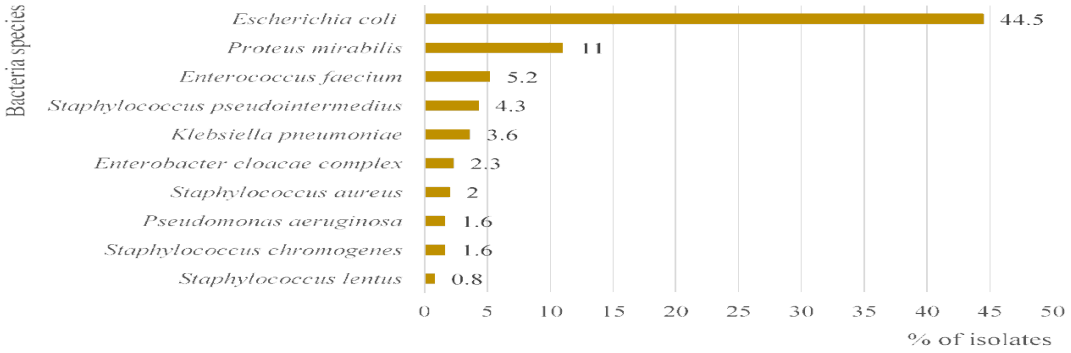


Figure 2: Bacteria species that predominate in the 5306 isolates with positive culture grown from urine samples from dogs and cats submitted to the INNO veterinary laboratory between 2017 and 2021 (Garcês *et al*., 2022).

In Egypt, hypervirulent type *K. pneumoniae* (hvKp) isolates were recovered from canine urinary samples in Al Qalyubia and Giza Governorates by a rate of 2% (Soliman *et al*., 2024). While. Farag *et al*., (2024) recorded that the second prevalent species isolated were *Proteus* spp. in canine isolates (16.1 %) and *Klebsiella* spp. in feline isolates (14.3 %). *Staphylococcus* spp. was isolated from canine cases only with the detection of methicillin-resistant *Staphylococcus pseudintermedius* (MRSP) strains at 3.6 %.

3. MYCOTIC URINARY TRACT INFECTIONS

Mycotic infections that frequently affect the urinary tract of dogs and cats are generally flourished when animal's immunological state become lower. Most of fungal UTIs are caused by an overgrowth of *Candida* spp. Although candida yeasts are normally present in the body as well as on the skin circumstances, it can disrupt the natural functioning of the body, when this occurs in the lower urinary tract it causes an infection which can become progressively. Fungal infections of the lower urinary tract often are asymptomatic, and may be uncovered when diagnosing another issue or during regular veterinary check-ups. Opportunistic mycoses in dogs and cats can result in a wide variety of symptoms, from localized infections to catastrophic systemic illnesses. Such fungi like *Microsporum canis* and *Sporothrix brasiliensis* may be important zoonotic agents (Eissa, 2023).

3.1. *Candida* species

Candiduria is the most commonly reported manifestation of candidiasis in the veterinary literature as shown in figure (3). In a retrospective study of urinary tract infections in dogs; risk factors for candiduria in pet animals were reported; comorbidities involved diabetes mellitus, antibiotic use in the preceding 30 days, immunosuppression, and lower urinary tract illness (Sykes *et al*., 2014).

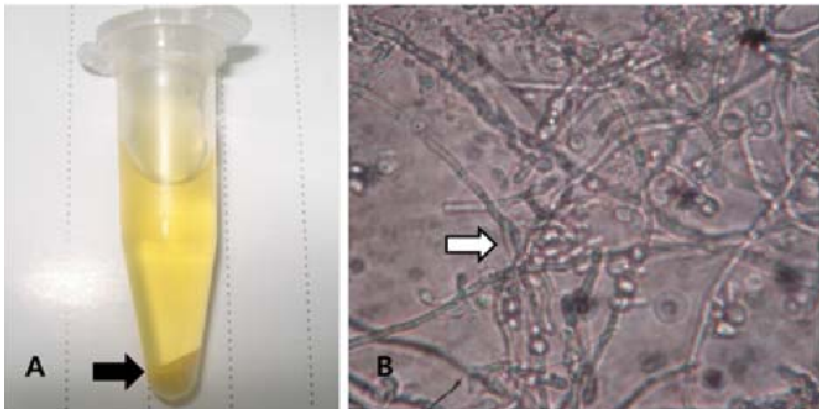


Figure 3: Urine sample (A) Cloudy sediment (black arrow) after centrifugation of urine. (B) Microscopic examination found pseudohyphae and budding yeast (white arrow) indicating *Candida* infection. 1,000×g (Sung *et al*., 2017).

Eighteen dogs belonged to 4 mixed breeds with candiduria without suspected systemic infection were identified. Three species of *Candida* were isolated, *C. albicans,* and *C. tropicalis*, and then *C. glabrata*. Ages ranged from 1-14 years. of age (median 7 years.). Antibacterial drug administration within the 30 days before diagnosis was recorded in 15 (83%) dogs. Potential causes of immunosuppression were recorded in 10 (55%) dogs. Lower urinary tract disease or urinary catheter placement was in the history of 6 (33%) dogs. Other urinary abnormalities include urethral tear during a cystoscopy, intermittent urinary catheterization, cystotomy, and obstructive prostatic cyst. One dog had been diagnosed with diabetes mellitus. On the other side, four *Candida* isolates were reported: *C. albicans, C. glabrata, C. tropicalis,* and *C. parapsilosis* in eight cats had candiduria. The risk factors comprised other lower urinary tract disorders, urethral avulsion secondary to trauma, perineal urethrostomy, and bladder rupture secondary to urethral obstruction. Four cats had received immunosuppressive medications. Administration of antibacterial drugs in the last 30 days was reported for 7 of the 8 cats (Reagan *et al.,* 2019).

In April 2011, a 3-year-old male Yorkshire terrier dog was referred to the Clinical Veterinary Hospital de Madrid, Spain, with a diagnosis of relapsing UTI. The dog had a history of ammonium urate bladder stones and had been treated previously with

marbofloxacin. Microscopic examination and culturing of urine specimens revealed the presence of yeasts. Yeast isolates recovered from clinical specimens were identified as *Candida tropicalis* on the basis of the morphology and pigmentation of their colonies on ChromAgar medium and also by sequencing the D1/D2 domains of the large subunit (LSU) rRNA gene (Álvarez-Pérez *et al.,* 2016).

3.2. Other Fungal Species

In October 2020, a 10-year-old male intact Border Collie dog presented to a specialty veterinary hospital at Michigan State University for a two-month history mural ureteral and bladder granuloma. The diagnosis, culture followed by MALDIToF, PCR, and sequencing was performed and identified *Scedosporium apiospermum* which is an opportunistic mold that is an emerging disease in humans and animals (Tsoi *et al.,* 2021). A nine-year-old female Labrador retriever suffered from urinary tract infection and was in the 14th day of a 21-day course of oral antibiotics amoxicillin-clavulanic acid in Sydney, Australia, in March 2017. The signs were hematuria, sanguinous vulval discharge, and urinary incontinence. The main compliance was the ultrasonographic observation of two intra-abdominal masses, "eumycetomas" which are chronic pyogranulomatous lesions caused by molds. Antifungal therapy was started on day 3 with oral itraconazole at 5mg/kg SID for 90 days. However, the dog continued to have urinary tract infections and urinary incontinence for the whole ninety days after treatment commenced. Due to cost constraints, euthanasia was elected on day 97. Amplification and sequence analysis of internal transcribed spacers and the partial large subunit of the 25–28s ribosomal RNA regions of fungus cultured was performed, identifying this as belonging to the *Curvularia* species (Herbert *et al.,* 2019). The *Blastomyces* spp. organism was detected in urine sediment obtained from a 2-year-old castrated male Doberman pinscher (Reagan *et al.,* 2019). A 2.5-year-old female spayed GSD dog was presented to the University Veterinary Teaching Hospital, Sydney, Australia, for investigation of polyuria, polydipsia, and urinary incontinence at night of at least four months duration. Fungal colonies were grown from both urine and lymph node aspirates. Molecular identification targeting the partial beta-tubulin gene revealed these colonies to be *Aspergillus deflectus* (Bennett *et al*., 2018). Cryptococcal UTI was diagnosed cytologically and via fungal culture in a male domestic shorthaired cat with stranguria and pollakiuria.

4. VIRAL URINARY TRACT INFECTION

Viral-induced disease is recognized, particularly of the upper urinary tract. However, it can be difficult to determine cause-and-effect relationships because viral-induced illness may occur in the absence of detectable replicating virus. Several viruses have been implicated in canine and feline disease, as shown in table(1) by Olin and Bartges, (2015).

Table 1: Viruses associated with urinary tract disease in dogs and cats. (Olin and Bartges, 2015).

Species	Upper Urinary Tract Disease	Lower Urinary Tract Disease
Canine	Canine adenovirus type I	
	Canine herpesvirus	
Feline	Feline coronavirus	Feline calicivirus
	Feline immunodeficiency virus	Bovine herpesvirus-4
	Feline leukemia virus	
	Feline foamy (syncytium-forming) virus	Feline foamy (syncytium-forming) virus

DIAGNOSIS

In 2019, the International Society for Companion Animal Infectious Diseases (ISCAID) released revised guidelines for the diagnosis and treatment of bacterial UTIs in pets. The

recommended diagnostic method for UTIs combines clinical signs, urinalysis; including dipstick testing, specific gravity measurement, and sediment cytology, haemato-biochemical analysis, radiography, and ultrasonography as well as bacterial culture results obtained from urine samples collected using cystocentesis (Barot *et al*., 2022).

4.1. Clinical examination

Clinical signs associated with UTI are variable and depend on the interaction of (1) virulence and numbers of the uropathogen, (2) presence or absence of predisposing causes, (3) the body's compensatory response to infection, (4) duration of infection, and (5) site (s) of infection. Pollakiuria, stranguria, dysuria, hematuria and inappropriate urination may be observed with lower UTI (Bartges, 2004).

4.2. Sampling

Free-catch urine sampling

When collecting a free-catch urine sample, a mid-stream sample is preferred. The initial urine that is voided contain cells, bacteria, and debris from the urethra and vulva or prepuce, and may not be a representative sample. Because female dogs are usually positioned with the vulva close to the ground when urinating, a shallow container (such as a pie pan) may be helpful. Quantitative analysis should be performed on all free-catch samples submitted for bacterial culture.

Obtaining a free-catch midstream urine sample from a cat is a difficult task. Removing the litter from the litter box or replacing it with nonabsorbent material, plastic packing material, etc. may allow collection of a suitable sample. Plastic wrap can be loosely placed over the litter to collect urine from declawed cats. Generally, the use of voided urine specimens for bacteriological culture is discouraged because contamination from external genitalia led to misinterpretation of laboratory results (Olin and Bartges 2015).

A study addressed the usefulness of voided specimens and determined veterinary cut-off values for significant bacteriuria. The results showed false negative culture results. False negative results are concerning, as they led to under-treatment, thereby posing a risk of complications to individual dogs. The veterinary cut-off yielded an accuracy of 95% with a sensitivity and specificity of 94%. (Sørensen *et al*., 2016).

Urinary catheterization

Male dogs are placed in lateral or sternal recumbency for catheterization. The penis is extruded from the prepuce, and the tip is cleaned with a dilute disinfectant solution to remove any debris or discharge. Sterile lubricant is placed on the tip of the urinary catheter, which is then placed in the urethral orifice, and the catheter is advanced into the bladder (Fig. 4). It is helpful to create a sleeve from the catheter packaging to maintain sterility while passing the catheter. Most female dogs need chemical restraint, such as lidocaine gel, to allow urinary catheterization (Figure 4).

Both male and female cats usually need chemical restraint to permit urinary catheterization. Generally, it is not routinely used for urine collection in cats unless it has been performed for another reason such as treating urethral obstructions (Reppas and Foster, 2016). After passing a urinary catheter to obtain a urine sample, the first few milliliters of urine should be discarded, as that is the portion most likely to have debris from the urethra. A second aliquot can then be obtained for urinalysis and quantitative culture if desired.

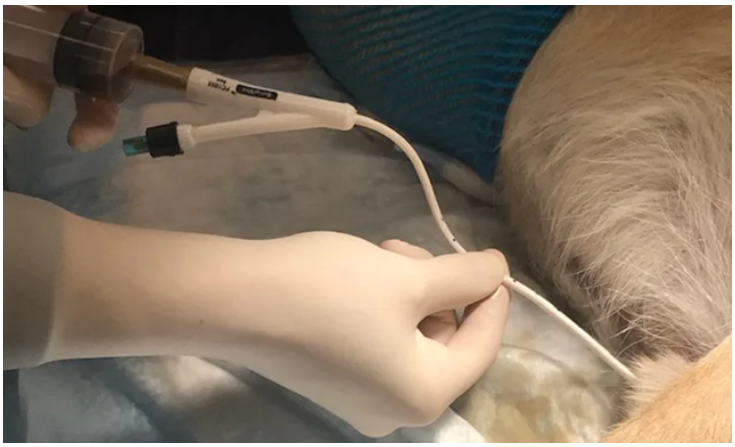


Figure 4: Urethral catheterization placement in male dog.
https://www.cliniciansbrief.com/article/urinary-catheter-placement-dogs

Cystocentesis

Cystocentesis allows the collection of an uncontaminated urine sample ideal for bacterial or fungal culture and can be performed on awake animals. It also allows appropriate timing of collection when timing is important.

The dog is usually positioned in dorsal recumbence. Palpating the bladder with one hand helps immobilize it while acquiring the sample. The needle should be angled caudally, toward the pelvic inlet, so that as the bladder empties, the needle is still in the lumen of the bladder (Fig. 5). It is also possible to use a lateral or standing approach when the bladder is palpable. A 1-inch, 22-gauge needle is preferred, and for very large or obese dogs, a 1.5 to 2-inch needle may be required.

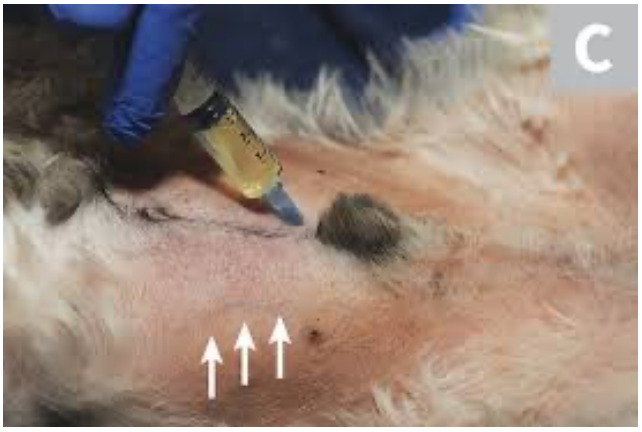


Figure 5: Cystocentesis (ie, obtaining urine directly from the urinary bladder by inserting a needle through abdominal wall).
https://www.cliniciansbrief.com/article/cystocentesis

In cats, cystocentesis is usually performed relatively easily unless they have idiopathic feline lower urinary tract disease (iFLUTD). These cats typically have a small bladder, and

any handling results in voiding; ultrasound-guided sampling may be more rewarding in these situations (Reppas and Foster, 2016).

Notably, with both cystocentesis and urinary catheterization, there is a risk of iatrogenic hematuria. Iatrogenic hematuria can occur if the needle is in contact with the opposite bladder wall. Other complications include puncture of the colon, laceration of the bladder, and laceration of the major blood vessels dorsal to the bladder. Inadvertent puncture of the colon caused bacterial contamination of the urine sample, and a mixed population of bacteria on the urine culture (Esparaz et al., 2016).

Storage of samples

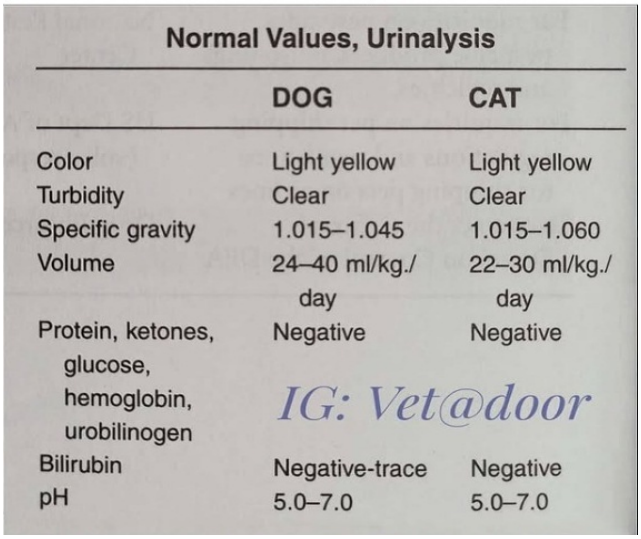
The storage condition was vital to maintaining the quality and accuracy of the urine samples. A study assessed different storage conditions of urine samples obtained from 30 dogs and 49 cats. The study showed that storing conditions at room temperature or refrigeration for 24 h do not impact the results of culture count in cat urine samples. For dog samples, chilled samples have a higher accuracy rate than room temperature samples, although the overall agreement was still satisfactory (Lien and Wang, 2023).

Additionally, Hedström, et al. (2021) declared that boric acid sponge preservation is a useful alternative to refrigeration of urine samples during transport. Reliable quantitative bacterial culture results can be obtained from canine urine up to 48 h after collection if urine is refrigerated and for at least 24 h if urine is stored using a boric acid-containing urine transport system.

4.3. Urinalysis

A urinalysis should be performed routinely as part of a minimum database and is an essential part of the diagnostic evaluation for all urinary and many metabolic diseases (Bartges, 2004).

A complete urinalysis assessment includes determining urine specific gravity (USPG) using a refractometer, evaluation of physical characteristics (color, clarity, and volume), biochemical parameters (urine pH, blood, glucose, ketones, bilirubin, urobilinogen, and protein) using analytic test pads on dipsticks, and microscopic sediment evaluation (RBC, WBC, organisms, epithelial cells, crystals, and casts) (figure 6). Collection of urine by cystocentesis is the preferred method when evaluating patients for UTI. If infectious prostatitis or vaginitis is suspected, different techniques were indicated (Reine and Langston, 2005).



Normal Values, Urinalysis		
	DOG	CAT
Color	Light yellow	Light yellow
Turbidity	Clear	Clear
Specific gravity	1.015–1.045	1.015–1.060
Volume	24–40 ml/kg./ day	22–30 ml/kg./ day
Protein, ketones, glucose, hemoglobin, urobilinogen	Negative	Negative
Bilirubin	Negative-trace	Negative
pH	5.0–7.0	5.0–7.0

Figure (6): Normal values, urinalysis in dog and cat (Bartges, 2004).

The physical characteristics of urine should be inspected when conducting urinalysis on every sample. These features are easily observed by both client and clinician alike and, as such, add no expense to case management. Urine volume, color, clarity, and odor are often overlooked. The veterinary team would do well to reconsider these urine properties because they provide unique insight about pet health and ongoing disease processes. Physical properties of urine also prompt pattern recognition. For example, observing turbid urine in canine or feline cases generates a list of the most common differentials, including pyuria, crystalluria, and bacteriuria. These clues guide decision-making as clinicians determine what is most likely ongoing in the affected case and how best to achieve a definitive diagnosis (Englar, 2022).

The dipstick was proven useful for rapid urinalysis to evaluate urine specific gravity (USG), pH, leukocytes, nitrites, glucose, proteins, ketones, urobilinogen, bilirubin, and blood. The USG and pH significantly changed during the neonatal period. Other parameters did not vary significantly in relation to age (Melandri *et al*., 2020).

Dipstick urinalysis is easily performable under every condition and is a cheap and repeatable diagnostic test, providing immediate results. A drop of urine can be put on each field of the strip to obtain reliable results using small volumes of urine. After dripping, the results were read after 60 seconds for all the parameters, except for leukocytes that were read at 120 seconds (Balogh *et al*., 2017).

Urinary pH is linked to alimentary habits; in carnivores, including dogs, it normally ranges between 6 and 6.5, being slightly acidic, and the urinary pH is influenced by alterations in systemic homeostasis.

Sediment evaluation

Normal urine should contain very few red blood cells. Owners may observe macroscopic hematuria, but microscopic hematuria will go undetected without sediment evaluation. Hematuria resulted from pyelonephritis, bladder infection, genitourinary tract inflammation, neoplasia, bleeding disorders, or trauma (McGuire *et al*., 2002). The existence of increased WBC indicated the existence of urinary tract inflammation, typically greater than 5 WBC/high power field (HPF). The presence of pyuria certainly raises concern about the presence of a bacterial urinary tract infection. Pyuria in a sample obtained via cystocentesis

indicated infection or inflammation of the kidneys, ureters, urinary bladder, or prostate. Any case with pyuria, particularly those with signs referable to the urinary tract (i.e., stranguria, pollakiuria, hematuria, polyuria), should have a urine culture and sensitivity performed. Dogs with diabetes mellitus are predisposed to urinary tract infection and many times do not have significant pyuria (McGuire *et al*., 2002).

Normal urine is sterile. Because bacteria can be found in the distal urethra and genital tract, samples obtained via free catch or catheterization may have some degree of contamination. Cystocentesis is the method of choice for obtaining the urine sample when bacterial urinary tract infection is suspected. Although bacteria can be visualized on microscopic examination, it is sometimes difficult to distinguish bacteria from debris. The presence of pyuria in the same sample would support the finding of bacteriuria. Microscopic examination of modified Wright's stained urine samples has been shown to be superior to traditional wet mounts when attempting to identify bacterial urinary infections in dogs. A bacterial culture and sensitivity should be performed on urine samples with microscopic evidence of bacteriuria (Swenson *et al*., 2004).

Occasionally, yeast or fungal hyphae may be seen in a urine sample and often represent contamination. In cats, true fungal urinary tract infections are most commonly seen associated with prolonged antibiotic and/or glucocorticoid therapy, aciduria, and the use of indwelling transurethral catheters. Fungal organisms can also be identified in the urinary bladder of pets with systemic mycoses (i.e., blastomycosis) (Werner and Norton, 2011).

Increased numbers of epithelial cells can be seen in association with infection, inflammation, irritation, and neoplasia. It is regarded as the gold standard method to attain an accurate diagnosis of bacteriuria and to gain the best course of treatment based on a decision-making process to limit the spread of resistance. Importantly, cultures should be repeated three to five days after the termination of antimicrobial therapy to ensure elimination of infection (Rampacci *et al*., 2018).

The quantitative bacterial culture (QBC) using the Calibrated Loop/Surface Streak Method (Fig. 7) is considered the gold standard for determining UTIs before initiation of antimicrobial therapy. It is necessary for differentiation of harmless bacterial contaminants from bacterial pathogens that facilitating accurate identification of specific bacterial species aids in selection of antimicrobial drugs. It also facilitates differentiation of recurrent UTIs caused by relapses from recurrent UTIs caused by reinfections (Strachan *et al*., 2022). One µL of urine sample was inoculated using a sterile inoculating loop at the surface of the standard nutrient agar plate with a single streak across the center. Then, spread the inoculum in a cross-zigzag manner (Fig. 7). After overnight incubation at 37°C, colonies were counted, and the number of colony-forming units (CFUs) per milliliter of urine was calculated. A quantitative urine culture demonstrated significant bacterial infection in the case of ≥ 103 CFU/ml in cystocentesis samples (Karah *et al*., 2020).

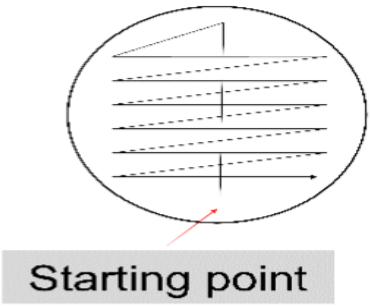


Figure 7. Urine culture using the calibrated loop/surface streak method.

The general-purpose media are sufficient for urine culture in low-resource settings; according to traditional guidelines, blood agar (non-selective medium) and MacConkey agar (selective and differential for Gram-negative rods) are probably the most commonly recommended and used media for routine urine cultures. As an alternative, cysteine lactose electrolyte-deficient (CLED) agar or chromogenic agar has been proposed as standard media for urine culture. Eosin methylene blue agar (EMB) was used as a differential for suspected *E. coli* colonies that were subcultured with the formation of a characteristic green metallic sheen. Mannitol salt agar is used as a selective medium for the isolation of *Staphylococcus* spp. Sabouraud agar should be added, in addition to the usual bacterial media, to culture the urine sample in particular care units or if yeasts have been seen by microscopic examination. The choice of media for routine urine culture should be made locally based on available resources and the desired approach of identification. Blood agar is replaced by nutrient agar in order to keep the costs low and since Gram-negatives have frequently accounted for the majority of anticipated pathogens. Isolates were identified based on colony morphology and characteristics (Public Health, 2020).

In freshly voided urine, the culture of ≥ 100 colonies of one type (number of bacteria is ≥ 105 cfu/mL) has usually been regarded as a cutoff for UTI. If 10–100 colonies of one type are counted (number of bacteria is between 104 and 105 cfu/mL), the result should be evaluated according to the clinical status. On the other hand, the probability of UTI is low if the number of colonies is <10 (number of bacteria is < 104 cfu/mL). For cultures containing two types of colonies, UTI is likely if ≥100 colonies are counted for at least one of the two types. Subcultures, for further identification and antimicrobial susceptibility testing, should be performed for each type counting ≥ 100 colonies, but it is also recommended to request a new sample. Notably, if both types have <100 colonies, for each one, UTI is not likely, and the sample is often contaminated. If there are more than two types of colonies, the sample is often contaminated. A new sample should be requested (CDC, 2020).

The sensitivity and specificity of Gram stain were evaluated on 103 canine urine samples acquired via cystocentesis and suspected UTIs. The centrifuged urine from the urine sediment preparation was used to make slides for Gram staining. These slides were allowed to air dry and then heat-fixed and stained with a commercially available Gram stain kit. A quantitative assessment of bacteria (none <3, 3–6, 6–10, 10–20, 20–50, 50–100, 100–200, 200–500, >500 bacteria/HPF) was recorded for each sample. Any slide with bacteria was

subsequently assessed for bacterial morphology (rod or cocci) and whether these bacteria stained Gram positive or Gram negative. Slides were considered positive for bacteriuria if ≥1 bacteria per HPF was observed and parallel to positive urine culture. The results revealed that Gram stain demonstrated 96% sensitivity, 100% specificity, 100% positive predictive values (PPV), and 93% negative predictive values (NPV) in the detection of bacteriuria for all dogs. Gram staining should be considered when bacteriuria is highly suspected and requires rapid identification while bacterial culture is pending (Way *et al*., 2013).

A number of 459 urine samples collected by cystocentesis from dogs suffered from UTIs; signs were prepared as unstained wet-mounted air-dried urine sediment. The preparations were subjected directly to modified Wright stain and examined for the presence of bacteria. Compared with the results of quantitative bacteriologic culture, modified Wright-stained preparations had a sensitivity of 93.2%, a specificity of 99.0%, PPV of 94.5%, NPV of 98.7%, and a test efficiency of 98.0%. So examination of urine sediment preparations by modified Wright-stained appeared to be a rapid, cost-effective method that significantly improved the sensitivity, specificity, PPV, NPV, and test efficiency of light microscopic detection of bacteriuria (Swenson *et al*., 2004)**.**

4.4. Biochemical Characterization

Positive urine culture is usually followed by a variety of biochemical identification tests to determine the species/genus of the implicated bacterium. The identification of bacterial pathogens is divided into two levels The Basic (level 1)" shall be available one day after receiving the sample and the advanced (level 2)." shall be ready in two days after receiving the sample (Table 2&3) (Karah *et al*., 2020).

Table 2. Basic biochemical identification of common uropathogens. (Karah et al., 2020).

Bacterium	Mac 1	Gram Stained Bacterial Cell Morphology	Glu 1	Oxi 1	Cat 1	PYR 1	Lanc 1
Enterobacterales	+	Red or pink rod-shaped	+	–	NA	NA	NA
***Pseudomonas*-like glucose-non-fermenter Gram-negative rods**	+	Red or pink rod-shaped	–	+	NA	NA	NA
***Acinetobacter*-like glucose-non-fermenter Gram-negative rods**	+	Red or pink rod-shaped	–	–	NA	NA	NA
Staphylococci	–	Clusters of purple or mauve sphere-shaped	NA	NA	+	NA	NA
Enterococci	–	Pairs or short chains of purple sphere-shaped	NA	NA	–	+	D
Streptococci	–	Chains of purple or mauve sphere-shaped	NA	NA	–	– *	B or D

Mac, MacConkey Agar; Glu, glucose fermentation; Oxi, oxidase; Cat, catalase; PYR, Pyrrolidone arylamidase; Lanc, Lancefield grouping; NA, Not Applicable. * Except for streptococci group A, which is not a common uropathogen.

Table 3. Advanced biochemical identification of common uropathogens (Karah et al., 2020).

Enterobacterales	Lac [1]	Ind [1]	Cit [1]	VP [1]	Ure [1]	Mot [1]	H_2S [1]	LDC [1]	Nit [1]
Escherichia coli	+	+	–	–	–	+	–	+	+
Klebsiella pneumoniae	+	–	+	+	+	–	–	+	+
Klebsiella oxytoca	+	+	+	+	+	–	–	+	+
Enterobacter cloacae	+	–	+	+	V	+	–	–	+
Enterobacter aerogenes	+	–	+	+	–	+	–	+	+
Citrobacter freundii	V	–	+	–	V	+	(+)	–	+
Citrobacter koseri	V	+	+	–	V	+	–	–	+
Proteus mirabilis	–	–	V	V	+	+	+	–	+
Proteus vulgaris	–	+	(–)	–	+	+	+	–	+
Providencia stuartii	–	+	+	–	V	(+)	–	–	+
Morganella morganii	–	+	–	–	+	+	–	–	+
Serratia marcescens	–	–	+	+	(–)	+	–	+	+

Glucose-non-fermenting Gram-negative rods	Oxi [1]	Lac [1]	Ind [1]	Cit [1]	VP [1]	Ure [1]	Mot [1]	H2S [1]	LDC [1]	Nit [1]
P. aeruginosa	+	-	-	V	-	(-)	+	-	-	V
A. baumannii	-	-	-	+	-	-	-	-	-	-

Staphylococci (catalase-positive)	Slide Agg [1]	Tube Coag [1]	Hemolysis	Salt Tol [1]	Mann [1]	Nov [1]
Staphylococcus aureus	+	+	V	+	+	S
S. saprophyticus	-	-	None *	+	+ * or -	R
S. epidermidis group	-	-	None *	+	-	S

Streptococci (catalase-negative)	Lanc [1]	Hemolysis	Bile esc [1]	6.5% NaCl tol [1]
Enterococci	D	No hemolysis *	+	+
Group D streptococci other than enterococci	D	β-, α-, or no hemolysis	+	-
Streptococcus agalactiae	B	β-hemolysis *	-	-

Lac, lactose fermentation; Ind, indole; Cit, citrate utilization; VP, Voges-Proskauer; Ure, urease; Mot, motility; H_2S, hydrogen sulfide production; LDC, lysine decarboxylase; Nit, nitrates reduction; Oxi, oxidase; Agg, agglutination; Coag, coagulase; Tol, tolerance; Mann, mannitol fermentation; Nov, novobiocin susceptibility; Bile esc, bile esculin hydrolysis; +, 90–100% Positive; -, 0–10% positive; (+), 76–89% positive; (-), 11–25% positive; V, variable.* Most strains.

4.5. Serological Identification

Smith *et al*. (2020a) evaluated urine myeloperoxidase (uMPO) as a rapidly available, accurate marker to predict urine culture results. They hypothesized that uMPO would be higher in dogs with a positive urine culture than in dogs with a negative urine culture and that uMPO could be used to aid in the accurate diagnosis of significant bacteriuria. The authors measured uMPO using a commercially available canine myeloperoxidase ELISA on urine samples from 98 dogs (forty-seven dogs had a negative urine culture and fifty-one dogs had a positive urine culture). The given results indicated that uMPO levels were significantly higher in samples that had a positive culture (median 2.13 ng/ml) versus samples that had a negative culture (median 1.07 ng/ml) ($p < 0.005$). Using a cutoff of 0.55 ng/ml, uMPO had a sensitivity of 70% and specificity of 69% to determine the presence of a positive culture.

A rapid immunoassay (RIA; BacVet) test utilizes a cocktail of monoclonal antibodies targeting a panel of bacterial surface proteins. It was carried out on twenty-one freely voided urine specimens obtained from dogs, which showed many signs of LUTIs according to the manufacturer's guidelines in the USA. The sensitivity of the RIA was 89%, specificity 100%, PPV 100%, and NPV 92%. The study revealed that the simple point-of-care RIA test can be performed in-office, rapidly, at low-cost, and without specialized training **(Grant et al., 2021)**.

Thereafter, Grant *et al*. (2023) evaluated the previous rapid immunoassay (RIA: BacVet) for the diagnostic performance immediately after urine collection and after refrigeration at 4 and 24 hours. The study was conducted on 40 voided urine samples from dogs with clinical signs of LUTIs. The results showed sensitivity, specificity, PPV, and NPV of the RIA were 100%, 88%, 82%, and 100%, respectively, and results were not different after 4 and 24 hours of refrigeration. The test is inexpensive, rapid, and accurate. Similarly, in an Australian study, a rapid immunoassay (RIA; RapidBac) was performed on forty-four urine specimens obtained by cystocentesis from 44 dogs according to the manufacturer's guidelines for diagnosis of bacteriuria. The results determined good sensitivity and excellent specificity, 81.8% and 95.5%, respectively, compared to urine culture (Sutter *et al*., 2023).

Microscopic Agglutination Test is the recommended technique for leptospirosis diagnosis, as reactivity to a serovar indicates exposure to a corresponding serogroup. Antibodies (IgM and IgG) were detected around 15 days post-infection, but little information was available on their duration in pets' blood. Clinical interpretation relies on paired serum titres, and some infected animals may produce lower results than the accepted 1:100. It is even possible that seroconversion in cats was expressed at a lower titre compared with dogs (Shropshire *et al*., 2016)**.**

The serum of 112 cats was investigated by MAT, detecting anti-Leptospira antibodies against 14 pathogenic serovars. Antibodies against 6 serovars—Poi, Bratislava, Arborea, Ballum, Pomona, and Lora—were detected in 15.3% (17/111) of cats (titers range: 20-320) as shown in figure (8) **(Donato et al., 2022).** A study in Indian Ocean islands addressed stray and domestic cats (n = 92) using a serological MAT. The results revealed a seroprevalence of 37.0% (34/92) (cut-off 1:40) without a significant difference in the living conditions of animals. The predominant serogroup was Icterohaemorrhagiae, but Ballum, Cynopteri, and Australis were also detected (Holzapfel *et al*., 2021).

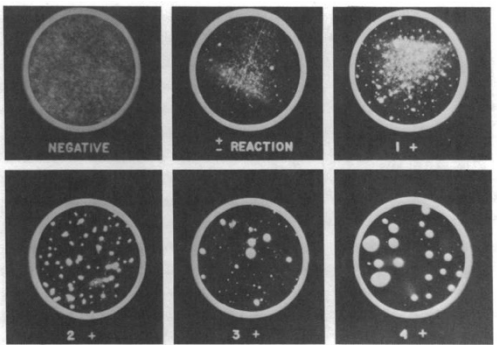


Figure (8): Microscopic Agglutination Test (MAT) (Donato et al., 2022).

Delaude *et al*. (2017) tested canine urine samples by MAT for antibodies against a panel of 12 serovars. Seropositivity (MAT ≥1:100) was most common to serovars Australis

(14.9%) and Bratislava (8.8%), followed by Copenhageni (6.1%), Canicola (5%), Grippotyphosa (4.5%), Pomona (4%), Autumnalis (2.7%), and Icterohaemorrhagiae (1.6%).

Microscopic Agglutination Test (MAT) test interpretation may be more reliable in cats than in dogs because no interference with vaccine antibodies exists as cats are not vaccinated. Furthermore, laboratory-reared young adult specific pathogen-free cats infected with *Borrelia burgdorferi* did not form antibodies against *Leptospira* species as a cross-reaction. The authors of that study suggest that positive *Leptospira* species MAT results from cats in the field are likely to reflect antibodies against *Leptospires* and not *B. burgdorferi* (Murillo *et al*., 2020).

ELISA used for leptospirosis identified the presence of specific IgM leptospiral antibodies earlier than MAT, 4–6 days post-infection. The main advantages of ELISA compared with MAT are the stability of antigenic preparations and the genus specificity, meaning all types of *Leptospires* can be diagnosed with a single antigenic preparation, irrespective of the causal serovar. In dogs, a combination of ELISA and MAT were recommended for leptospirosis diagnosis (Murillo *et al*., 2020). An IgM immunoblot assay was 88% sensitive in the first 3 days of human leptospirosis compared with 2% for the MAT. Use of rapid, broadly reactive antibody assays as screening tests before performing the more specific and cumbersome MAT may help decrease false negative test results relating to inadequate serovar inclusion in the MAT. Ideally, they should detect antibodies that react only with pathogenic serovars. Recombinant LipL32-based assays recently were evaluated and was found to be sensitive and specific in dogs and humans compared with MAT testing (Sykes *et al*., 2011). Rapid patient-side tests for leptospirosis diagnosis were developed. Curtis *et al*. (2015) performed a recombinant LipL32-based rapid in-clinic ELISA (SNAP Lepto) for the detection of antibodies against *Leptospira* species in dogs. Neither of the tests distinguishes between serovars, nor do they provide a titre magnitude. The first test, 66, is based on the detection of *Leptospira*-specific IgM and has demonstrated a sensitivity and specificity of 100% and 95.3%, respectively. It can therefore detect dogs with clinically suspected acute leptospirosis. Dogs previously vaccinated or suffering from an acute but subclinical infection can also produce positive results. A LipL32-based in-clinic ELISA for the rapid detection of *Leptospira* specific antibodies in dogs is not IgM specific, but the study authors considered it a convenient tool to assess *Leptospira* antibody status in dogs. Neither rapid test techniques nor ELISA to diagnose leptospirosis in cats have yet been developed.

4.6. Molecular Identification

Generally, the significance of molecular-based techniques is relied on that they elucidate a reliable, quick, precise, and low-cost diagnosis, especially in non-culturable or fastidious pathogens.

Melgarejo (2021) used next-generation sequencing (NGS) and stated that the diversity and abundance of bacterial and fungal communities varied between urine samples from different dogs.

Pulsed-field gel electrophoresis (PFGE) identified 31 PFGE patterns among the 43 *E. coli* isolates, which could be classified into nine and four groups showing > 80 % and > 95 % similarity. Homology ranged from 25% to 100%, indicating that canine urinary *E. coli* isolates exhibited a high degree of genetic polymorphism (Yu *et al*., 2020).

A quantitative real-time PCR assay was developed for the diagnosis and monitoring of mycoplasma UTIs in an English Cocker Spaniel dog. Attempts to culture organisms from purulent urine failed, and empirical antibiotic therapy did not resolve the pyuria. A mycoplasma species most closely resembling *Ureaplasma canigenitalium* was identified in urine samples by conventional PCR and sequencing. The qPCR method has provided rapid results and achieved verified successful treatment (Hemmatzadeh *et al*., 2019). In *Leptospira* diagnosis, PCR-based techniques played a very crucial role for detection; partial rrs gene (16S rRNA) sequencing identified *Leptospira interrogans* in all PCR-positive samples, and Leptospira DNA was detected in renal tissue, urine, and blood (Holzapfel et al., 2021). A real-time polymerase chain reaction targeting the lipL32 gene of pathogenic *Leptospira* was conducted on feline blood and urine samples. *Leptospira* spp. DNA was found in 3% (4/109) of blood and 9% (10/111) of urine samples (Donato *et al*., 2022).

Positive qPCR canine samples were subjected to 16S rRNA and secY gene phylogenetic analysis. The recovered strains were characterized by multilocus sequence typing. Phylogenetic analysis revealed that 10 dogs had *L. interrogans* infection. Three dogs (3/13) had *L. santarosai* infection. The secY phylogenetic analysis revealed that the *L. santarosai* sequences clustered separately from those obtained from other hosts. The results suggested a genetic distinction between lineages of Brazilian *L. santarosai* maintained by dogs and other animal hosts (Miotto *et al*., 2018).

PCR directly identifies leptospiral DNA. It does not determine the infecting serogroup or serovar, but it can indicate the *Leptospira* species. The test can be performed on blood, urine, cerebrospinal fluid, and body tissues. In cases of acute leptospirosis, this would be the test of choice to perform on blood and urine in cats. Compared with culture, PCR gives fast results, contributing to an early diagnosis. Real-time PCR techniques were recommended due to their greater sensitivity and specificity. Genes that have more than one copy in the genome, such as lig or rrs, were selected for increasing the sensitivity of the technique. Genes present only in the pathogenic species can also be added, as they will increase the specificity of the test. A positive PCR result means that leptospiral DNA is present in the sample. In acute infections or in chronic carriers, the test would be positive in urine, indicating that bacterial DNA is being shed. However, negative results in blood and urine do not rule out leptospirosis, as leptospiraemia is transient (only occurring in the initial phases of the disease); also, results are usually negative if the pet has received antibiotic therapy, and shedding in urine can be intermittent (Dorsch *et al*., 2017). MicroRNAs (miRNAs), classified as non-coding RNAs, regulate various metabolic systems and viral life cycles. Feline foamy virus (FFV) was identified in feline urine samples using expression of miRNAs and confirmed by application of dual-luciferase reporter assay. It was found that the seed sequences of the miRNAs identified in the study were conserved among all previously reported FFV isolates. These obtained results suggest that FFV-derived miRNAs played a pivotal role in FFV infection (Aso *et al*., 2021)**.**

4.7. Ultrasonography for pet animals

It is a significant diagnostic tool and an ideal noninvasive approach to evaluate urinary tract disorders because it is easy to implicate, low cost, and provides high real-time contrast resolution. Ultrasonography is commonly utilized as the first diagnostic technique in

instances of hematuria or dysuria (Fig. 9), as it enhances the diagnosis of cystolith, nephroliths, renal mass, cystitis, and hydronephrosis (Barot *et al*., 2022).

For ultrasonographic examination, the animals were restrained and positioned in lateral or dorsal recumbence. The abdomen was shaved and coated with an ultrasonic coupling gel, then examined with a probe of 9–3 MHz. Ultrasonography was used to inspect the urinary bladder's wall thickness, urine content, and turbidity, or the presence of any abnormalities such as cystic calculi, polyps, or tumors. The kidneys were examined for the presence of cysts, abscesses, or any abnormalities, and the male animals were inspected for any prostatic cyst or abscess to be excluded (Mantis, 2008).

Figure (9): Ultrasonography for dogs (Barot et al., 2022).

4.8. Clinical diagnostic approaches

Sporadic bacterial cystitis

Sporadic bacterial cystitis is a common condition in dogs and less encountered in cats, in which a bacterial infection of the bladder results in inflammation and corresponding clinical symptoms, which can involve dysuria, pollakiuria, stranguria, hematuria, or a combination of these symptoms. Previously, 'simple uncomplicated' or 'complicated' urinary tract infection (UTI) has been used to describe bacterial cystitis in dogs and cats (Jessen *et al*., 2015)**.**

Diagnosis is based on the presence of lower urinary tract signs, ideally with concurrent evidence supporting bacterial cystitis (e.g., hematuria, pyuria, cytologically evident bacteriuria) and bacterial culture results.

Urinalysis (dipstick, urine specific gravity, and cytological examination of the sediment) should be performed in all cases to provide supporting evidence and detect potential comorbidities (e.g., glucosuria, crystalluria).

Specimens for culture should be collected by cystocentesis unless there is a contraindication (which would rarely be present in animals with sporadic cystitis) or significant difficulties in sample collection are anticipated (e.g., from a large, morbidly obese dog). Ultrasound guidance facilitates cystocentesis and assess the bladder for abnormalities such as uroliths or masses (Patterson *et al*., 2016).

Culture of voided samples should only be performed when cystocentesis is contraindicated because of the potential for both false positive and false negative cultures.

Voided samples should only be cultured if they are refrigerated and processed by the diagnostic laboratory within a few hours or cultured in-house (Sørensen *et al*., 2016). The level of growth (105 CFU/mL), bacterial species (i.e., and whether pure growth is present) are important factors to assess when evaluating culture results from voided samples, along with urine cytology and clinical signs.

Recurrent bacterial cystitis

Recurrent bacterial cystitis definition in veterinary medicine is similar to that in human medicine. A diagnosis of three or more episodes of clinical bacterial cystitis in the preceding 12 months or two or more episodes in the preceding 6 months (Arnold *et al*., 2016). Recurrent cystitis may result from relapsing or persistent infection or reinfection. Consideration of which of these is likely present can be useful for determining the diagnostic plan (e.g., evaluation of a nidus of infection vs. reasons for susceptibility to repeated infections). Diagnosis since recurrent cystitis can be associated with ultrasound, plain radiography, contrast imaging, or possibly cystoscopy, they may be considered for refractory clinical recurrent cystitis cases to investigate further for underlying comorbidities and obtain a biopsy of the bladder mucosa, if clinically indicated. If clinical signs persist despite negative urine cultures, biopsies of bladder mucosa can be obtained during cystoscopy and submitted for culture and histological examination to evaluate for deep-seated bladder infections or other causes.

1) Urine culture, ideally from a sample collected via cystocentesis, should be performed in all animals with recurrent cystitis.

2) A diagnostic plan should be established for every animal with recurrent cystitis.

3) If the pathogen isolated from the animal with recurrent infection is different from previous organisms isolated, reinfection is likely, and efforts should be undertaken to identify and address any predisposing factors.

Upper urinary tract infections (pyelonephritis)

Pyelonephritis is an infection of the renal parenchyma that can occur from ascending infection or bacteremia, often with *Enterobacteriaceae* causing the majority of infections (Wong *et al*., 2015). In human medicine, acute pyelonephritis is classified as 'uncomplicated' or 'complicated'. Uncomplicated implies there is no underlying comorbidity; complicated suggested the presence of a systemic disease such as diabetes mellitus or neoplasia or an anatomical/obstructive disorder such as urinary stone disease or ectopic ureter**.** Ascending infection can result from clinically evident lower urinary tract disease. Additionally, leptospirosis must be considered in endemic regions (Sykes *et al*., 2011).

A definitive diagnosis is difficult, and signs attributable to pyelonephritis can be vague. As opposed to bacterial cystitis, where morbidity is relatively low, pyelonephritis can result in severe and rapid kidney injury. Thus, rapid diagnosis is important for proper treatment. Diagnosis of acute pyelonephritis can be suspected based on positive aerobic bacterial urine culture when accompanied by systemic signs such as fever, lethargy, and/or polyuria/polydipsia or renal pain on abdominal palpation. Laboratory findings of azotemia, casts, and peripheral neutrophilia with or without left shift. However, animals with acute pyelonephritis may be oliguric or anuric or have vague clinical signs. Imaging findings such as renal pelvic dilation and/or blunting of the renal papilla on ultrasound examination may be noted but are nonspecific (D'Anjou *et al*., 2011).

Increased concentrations of biomarkers such as serum creatinine or serum symmetric dimethylarginine (SDMA) can also support the presence of renal injury (Dahlem *et al*., 2017)

in association with bacteriuria, but are indicators of glomerular filtration rate and are not specific for bacterial pyelonephritis as the cause of kidney injury.

- Culture cystocentesis specimens and susceptibility testing should always be performed.
- Obtaining a urine specimen for cytology and culture by pyelocentesis should be considered, particularly if results of culture of a cystocentesis specimen are negative, or when a cystocentesis specimen can not be obtained.
- Blood cultures are recommended at the same time as urine cultures in immunosuppressed or febrile animals.
- It is important that culture specimen submissions indicate that pyelonephritis is suspected to ensure that urine breakpoints are not applied.
- If multiple organisms are isolated from urine, the suspected relative relevance of these should be considered. This assessment would include the bacterial species and colony counts.
- Evaluation for leptospirosis should be considered in culture-negative dogs by use of serological testing and PCR (Sykes *et al*., 2011).

Subclinical bacteriuria

Subclinical bacteriuria is defined as the presence of bacteria in urine as determined by positive bacterial culture from a properly collected urine specimen, in the absence of clinical evidence of infectious urinary tract disease. Terminology such as 'urinary tract infection' or 'occult infections' has been used in reference to animals with positive bacterial cultures but no clinical signs of lower urinary tract disease (Peterson *et al*., 2012); however, this terminology now should be avoided.

The term bacteriuria has been used to describe cases where bacteria are visible cytologically, irrespective of culture results (Way *et al*., 2013); however, diagnosis of bacteriuria should be based on culture (Nicolle *et al*., 2005). Cytological evaluation is an important part of urinalysis in animals with suspected urinary tract disease. An increased urine sediment white blood cell count has been associated with increased odds of a positive culture (O'Neil *et al*., 2013), but this has not been a consistent finding (McGuire *et al*., 2002). Poor agreement between cytological detection of bacteria and positive urine culture has been reported in dogs (McGhie *et al*., 2014). Increased urine sediment red blood cell count is also not predictive of positive cultures (O'Neil *et al*., 2013). Thus, cytological data are useful adjunctive data to assess animals with potential urinary tract disease but may not be highly predictive of culture results, infectious disease, or correlate well with clinical signs of upper or lower urinary tract disease. Similarly, proteinuria is not predictive of subclinical bacteriuria (Lippi *et al*., 2022).

Subclinical bacteriuria is common, even in individuals with no known predisposing factors. Rates of 2.1–12% have been reported in healthy dogs (McGhie *et al*., 2014), with higher rates (15–74%) in groups such as dogs with diabetes mellitus, morbidly obese dogs, puppies with parvoviral enteritis, dogs with acute disk herniation, chronically paralyzed dogs, and dogs treated with cyclosporine or glucocorticoids (Baigi *et al*., 2017). Study of subclinical bacteriuria has been limited in cats, and the prevalence may be lower than reported in dogs; however, rates of 1–13% have been reported in healthy cats (White *et al*., 2016; Puchot *et al*., 2017).

No evidence of an association between subclinical bacteriuria and risk of development of cystitis or other infectious complications has been reported in dogs or cats (Wan *et al*., 2014; White *et al*., 2016).

Culture of urine from animals with no evidence of urinary tract disease should not be performed when there would be no indication to treat based on a positive culture result (McGuire *et al*., 2002).

A diagnosis of subclinical bacteriuria is made based on identification of bacteria by culture of urine collected via cystocentesis in an animal without clinical signs attributable to bacterial cystitis.

Cystocentesis is the preferred method for urine collection, and urine should not be collected by other methods unless there are contraindications to cystocentesis.

Bacterial cell count, typically expressed as CFU/mL, can not differentiate subclinical bacteriuria from bacterial cystitis. Subclinical bacteriuria is differentiated from bacterial cystitis by the absence of clinical signs and not by the bacterial load. There is no evidence that high CFU counts indicate a greater risk of disease development. Subclinical bacteriuria is also not defined by the presence or absence of pyuria on urine sediment examination.

Re-testing of bacteriuric animals is not recommended.

6. TREATMENT

Generally according to ISCAID guidelines, UTIs are treated with antibiotics. Initially, an antibiotic 'empirical' may be prescribed that targets the most likely bacteria causing infection. After the culture finalizes (which may take a few days), the veterinarian specialist may need to change the antibiotic if the results indicate the first antibiotic is not ideal. Antimicrobial therapy is indicated in most cases while awaiting culture and susceptibility results to relieve patient discomfort. In most situations, amoxicillin (11–15 mg/kg PO q8h), amoxicillin-clavulanic acid, and trimethoprim-sulphonamides (15 mg/kg PO q12h) are considered as the first empirical antimicrobial choices for UTI treatment in pets. Meanwhile, nitrofurantoin, fluoroquinolones, and 3rd generation cephalosporins are only recommended if resistance to first-line antimicrobials is detected or the condition of the pet warrants it (Weese *et al*., 2019).

The intention of antimicrobial therapy is to eliminate the bacterial growth in the urinary tract utilizing an antimicrobial agent in a cost-effective manner. The degree of infection is dependent on the susceptibility of the bacteria to the concentration of the antimicrobial agent reached in the urine. Antimicrobial agents can eliminate the bacterial growth in the urinary tract within an hour. An effective antimicrobial agent generally attains minimal inhibitory concentration (MIC) both in the serum and urine of healthy adults.

The urinary levels are frequently manyfold larger than the serum levels. However, the serum levels are critical in cases with urinary infections. Traditionally, antimicrobial therapy has been used for the treatment of UTIs using either a prophylactic or therapeutic approach.

Antibiotics such as penicillins, sulfanilamide, and cephalexin have been used in the RUTI therapy (Bader *et al*., 2020). Following the last update, treatment of subclinical bacteriuria is not indicated for humans, dogs, or cats". Up to 12% of healthy dogs and 13% of healthy cats have subclinical bacteriuria. Even if pyuria is present along with bacteriuria, antibiotic therapy is not recommended in the absence of clinical signs of cystitis **(Acierno *et al*., 2024)**.

6.1. Antimicrobial Susceptibility Test (AST)

The AST is usually done by the Mueller-Hinton broth micro-dilution method.

Assays were performed according to CLSI guidelines in triplicate, with the exception of the indicated procedural variations and use of nonstandard AST media. The experimental parameters are varied one at a time during testing, and results were compared with those obtained using the standard reference Broth microdilution (BMD) method or Cation Adjusted Mueller Hinton Broth (CAMHB). Falcon 96-well polystyrene plates were used, except for indicated analyses using Falcon 96-well polypropylene plates. Assay plates were incubated for 18 h at 35 ± 2°C in ambient air, and MICs are determined visually unless otherwise indicated. MIC50 and MIC90 values were defined as the minimum concentration of an antimicrobial agent necessary to inhibit the growth of ≥ 50 % and ≥ 90 % of the isolates, respectively. MIC50 and MIC90 determinations are important for assessing the efficacy of a given antimicrobial. Reference strains of tested bacteria were used as quality control strains. Quality control standards and test results were interpreted with reference to CLSI documents (CLSI, 2023).

6.2. Clinical Therapeutic Approach

Sporadic bacterial cystitis

Clinical signs are a result of inflammation. In dogs, a decision to start antimicrobial therapy while awaiting culture results (if samples are submitted) is reasonable. However, there is evidence from humans that analgesics alone may be as effective as antimicrobials in uncomplicated cases (Gágyor *et al*., 2015; Bleidorn *et al*., 2016), which could be applied to sporadic cystitis in cats and dogs. Consideration can be given to prescribing an initial course of analgesics (e.g., NSAIDs) and adding antimicrobials 3–4 days later if clinical signs persist or worsen. Regardless, NSAIDs (use with caution in cats) should be considered during the initial treatment period to help ameliorate clinical signs. To avoid unnecessary antimicrobial use in cats, withholding antimicrobial treatment pending the result of aerobic urine culture is reasonable.

Optimal empirical choices vary based on the pathogen and resistance patterns in the region. However, amoxicillin is a reasonable first choice in most areas. If amoxicillin without clavulanic acid is not readily available, use of amoxicillin/clavulanic acid is reasonable. Evidence of a need for clavulanic acid is lacking, and it may not be necessary, even in infections with beta-lactamase-producing bacteria, because of the high amoxicillin concentrations that are achieved in urine. Trimethoprim-sulfonamides (trimethoprim-sulfadiazine, trimethoprim-sulfamethoxazole) are other first-tier options but may be associated with greater adverse effects. However, the likelihood of adverse effects is low with short courses of therapy as are recommended below (Weese *et al*., 2019). The recommended

duration of therapy is 3–5 days. The short end of that dosing period may be optimal, but veterinary research to support this is currently limited (ACADI, 2019).

Nitrofurantoin, fluoroquinolones, and 3rd generation cephalosporins should be reserved for sporadic cystitis where amoxicillin (±clavulanic acid) and trimethoprim-sulfonamide are not appropriate based on culture and susceptibility testing results or case factors. These drugs can be effective but uncommonly needed, and their use in animals is scrutinized because of concerns regarding antimicrobial resistance and public health. Rarely, the dosing regimens that some of these drugs offer (e.g., once daily administration or single injection) may be required for proper treatment, and owner compliance is an important consideration. However, clinicians must differentiate between need and convenience when choosing one of these drugs over recommended first line options. Additionally, the US FDA has discouraged routine use of fluoroquinolones in humans for uncomplicated infections because of adverse effects on joint, tendon, and nerve damage (Weese *et al*., 2022). It is not necessary to administer fluoroquinolones in most cases of sporadic cystitis when other alternatives exist. Treatment of intact male dogs with no evidence of prostatitis, as well as dogs with comorbidities not involving the urinary tract and with non-recurrent infections, should be approached as described above, with the understanding the underlying factors might increase the likelihood of recurrence.

Veterinarians should be aware of local (ideally clinic-level) antimicrobial susceptibility patterns to help guide empirical choices. If the expected incidence of treatment failure to a given antimicrobial increases, an alternate antimicrobial should be considered. However, care must be taken when interpreting potentially biased data, such as culture data obtained predominantly from specimens submitted from animals with refractory or recurrent cystitis. Veterinarians are encouraged to collect surveillance data on pathogen susceptibility patterns and clinical response to guide optimal empirical therapy. Consultations with their laboratory microbiologists are encouraged (Weese *et al*., 2019).

Infusion of substances (e.g., antimicrobials, anti-inflammatories, biocides) into the bladder via urinary catheter is not recommended because of a lack of evidence of efficacy and the potential for iatrogenic infection, trauma from catheterization, or irritation of the bladder from infusates. There is currently no evidence that adjunctive treatment measures (e.g., cranberry extract, D-mannose) are useful for treatment of sporadic cystitis (Stapleton *et al*., 2011).

Follow up

Lack of clinical response within 48 h of starting appropriate antimicrobials should prompt further investigation to determine whether cystitis is actually present and identify complicating factors.

If initial culture results indicate resistance to the empirical antimicrobial that was chosen, the drug should be changed unless there has been a good clinical response.

Empirically changing antimicrobials in response to poor initial response to treatment is not recommended. If clinical failure has been documented, the cause must be determined, as it may be unlikely that a different drug will result in a better outcome. Animals with partial or

complete clinical failure to treatment should be re-examined. Unless the initial culture results indicated resistance to the antimicrobial that was used empirically, or poor owner compliance is documented, prescribing a new course of antimicrobials in the absence of further investigation of the reason for clinical failure is not recommended (Weese *et al*., 2011).

Post-treatment urinalysis or urine culture is not recommended for sporadic cystitis when clinical signs have resolved.

Recurrent bacterial cystitis

Previously, guidelines supported long durations (4 weeks) of antimicrobials for recurrent cystitis (Weese *et al*., 2011). However, recurrent cystitis encompasses a broad range of conditions, including repeated and relatively uncomplicated infections that likely respond quickly to antimicrobials and others with marked bladder pathology that complicates treatment. Broad recommendations for treatment duration are difficult because of this variation.

The goals of treatment must be considered. The primary objective is clinical cure with minimal risk of adverse effects (including antimicrobial resistance). Microbiological cure (elimination of the offending organism) is desirable but not necessarily achievable or required for short- or long-term clinical resolution.

Depending on the severity of clinical signs and the owner's ability to observe the animal, treatment with analgesics (e.g., NSAIDs) alone could be considered while awaiting urine culture results. However, empirical therapy is reasonable and should be approached as described for 'sporadic bacterial cystitis'.

If empirical antimicrobials are initially prescribed, antimicrobial choice should be reassessed when culture results are available. If the bacterial strains isolated are reported to be susceptible to the antimicrobial drug selected, no change in treatment plan is required. If one or more isolated strains are not susceptible, the animal's response should be considered. If clinical cure is documented, it is acceptable to continue with the initial antimicrobial that was chosen. If clinical failure is documented, an antimicrobial change is indicated.

Long-term therapy is not automatically warranted for recurrent cystitis, even in dogs with underlying comorbidities such as diabetes mellitus, and this is especially true if recurrent disease appears to be caused by re-infection. Short (3–5 days) durations should be considered for reinfection. Longer courses (7–14 days duration) may be reasonable in persistent and potentially relapsing infections if factors that inhibit response to antimicrobials, such as bladder wall invasion, are suspected to be present. In those situations, drugs that are ineffective against *Escherichia coli* in tissue (e.g., amoxicillin/clavulanic acid) should be avoided (CLSI, 2023).

Intra-vesicular administration of antimicrobials or biocides is not recommended.

Follow up

Clinical cure rates are poorly established for recurrent cystitis. Most monitoring is based on clinical response, as data on the expected or desired microbiological, cytological, or hematological response to treatment are lacking.

When short (3–5 days) durations of treatment are being used, culture during treatment is not recommended. When longer durations of treatment are being used, the benefit of intra-treatment culture is unclear (Weese *et al*., 2011).

When longer durations of treatment are being used, urine culture is reasonable to consider after 5–7 days of treatment; however, the approach to a positive or negative result should be considered in advance. Positive cultures indicate the need for evaluation of compliance and further diagnostic testing to determine why the bacterium has not been eliminated, not simply a change in antimicrobial, particularly if clinical cure has been documented. Negative results could be used to help determine when to stop therapy if a long course of treatment is being used but are not a guarantee of microbiological cure.

Culture of urine specimens, ideally collected by cystocentesis, can be considered 5–7 days after cessation of antimicrobials in animals where clinical cure is documented. However, this should be used as part of the diagnostic process to help differentiate relapse, re-infection, and persistent infection, and to guide potential future diagnostic testing, not as an indication of a need to treat. The presence of bacteriuria post-treatment should be approached as described under 'Subclinical bacteriuria'. If client compliance is deemed to have been adequate, referral to a specialist should be considered to explore reasons for microbial persistence or rapid re-infection (CLSI, 2023).

Prevention

Balancing potential efficacy, resistance, and adverse effects is a challenge, and there are few published studies in dogs or cats. Single nightly dose nitrofurantoin has been anecdotally used in dogs to prevent recurrent cystitis, but efficacy data are lacking. Furthermore, adverse effects of these drugs exist, and there is concern for the selection of resistant bacteria. Alternative approaches for prevention and treatment of recurrent cystitis that have been investigated in human beings as well as animal UTI models include the use of cranberry extract (McMurdo *et al*., 2009), cranberry juice (Stapleton *et al*., 2011), probiotics (Rodrigues *et al*., 2014), live biotherapeutic products (such as asymptomatic strains of *E. coli*) (Segev *et al*., 2018), vaccines (Billips et al., 2009), and various other alternative therapies, such as methenamine, D-mannose, and intravesicular or orally administered glycosaminoglycans (Mansour *et al*., 2014). There has been limited study in dogs. In one study, cranberry extract prevented adherence of *E. coli coli*strains isolated from dogs to canine kidney cells, and six dogs with recurrent UTI treated with cranberry extract did not develop UTI when monitored for 2 months (Chou *et al*., 2016), but a placebo-treated control population was not studied. In another prospective, randomized, placebo-controlled study of 94 dogs with thoracolumbar disk herniation, cranberry extract did not appear to reduce the prevalence of bacteriuria, with six dogs in the placebo and 11 dogs in the cranberry extract group developing bacteriuria over a 6-week period (Olby *et al*., 2017). Live biotherapeutic products appear promising for treatment of recurrent cystitis, with a preliminary study reporting complete or nearly complete clinical cures in four out of nine dogs with recurrent cystitis in response to instillation of *E. coli* 2-12 (Segev *et al*., 2018).

Prophylactic antimicrobial therapy for dogs and cats is not recommended.

Treatment with a short course (3–5 days duration) therapy ideally based on susceptibility testing, is most appropriate to alleviate clinical signs, with a focus on clinical rather than microbiological cure.

There is insufficient evidence to recommend the administration of cranberry extract products and other alternative therapies at this time.

There is insufficient evidence to recommend administration of methenamine. Data from human medicine suggest it may be effective in some (but not all) human populations with recurrent cystitis (Lee *et al*., 2012); however**,** evidence of efficacy and safety in dogs and cats is lacking. Conversion to the active form (formaldehyde) requires low pH, which is not always assured in dogs and cats with recurrent cystitis.

Upper urinary tract infections (pyelonephritis)

Treatment should be initiated immediately, while awaiting culture and susceptibility results.

Initial treatment should involve antimicrobial drugs known to have local or regional efficacy against *Enterobacteriaceae*. If regional data are supportive, a veterinary fluoroquinolone or cefpodoxime are reasonable first choices. Cefotaxime and ceftazidime are options for IV administration (Table 4).

If ascending infection is suspected, recently obtained urine culture results should be the basis of initial therapy (remembering that serum breakpoints must be considered). If hematogenous spread is suspected, initial therapy should be based on cultures of blood or the infected site whenever available (CLSI, 2023)**.**

Oral antimicrobial therapy is recommended in animals that otherwise appear systemically well and have normal appetites. Intravenous therapy is recommended for animals that are dehydrated, hyporexic, anorexic, or lethargic as recommended in humans (Strohmeier *et al*., 2014).

- Culture and susceptibility data should be reviewed when results are received.
- If combination therapy was initiated empirically and the isolate is susceptible to both drugs, one might be discontinued if supported by evidence of clinical response.
- If resistance is reported to one of the drugs, that antimicrobial should be discontinued. A second drug to which the isolate is susceptible should be substituted if the patient has not responded sufficiently; substitution is not necessary if the patient response has been sufficient (Strohmeier *et al*., 2014).
- If resistance is reported to both antimicrobials and clinical evidence of improvement is not evident, antimicrobial treatment should be changed to a drug to which the offending organism is susceptible *in vitro*.
- If resistance to the drug(s) that are used is reported but there has been good clinical response, continuation with the initial therapy could be considered, provided there are not

other reasons (such as fluid therapy) that might explain clinical improvement. Otherwise, a change in antimicrobial is indicated.

- Consultation with a specialist (veterinary clinical microbiologist and/or veterinary pharmacologist/pharmacist) is indicated with multidrug-resistant organisms (Strohmeier *et al*., 2014).

A diagnosis other than bacterial pyelonephritis should be considered if there is no improvement in systemic signs, hematology, or serum biochemistry (e.g., azotemia, acute phase proteins) within 72 h of antimicrobial therapy and the results of culture and susceptibility indicate susceptibility to the antimicrobial used and there is confidence in client compliance. At that time, consideration should be given to a diagnosis of subclinical bacteriuria (with discontinuation of antimicrobial therapy) or for the presence of uncontrolled underlying factors (e.g., ureteroliths, neoplasia) that would need to be addressed to resolve the underlying infection (CLSI, 2023).

Treatment for 4–6 weeks has previously been recommended for pets (Weese *et al*., 2011). However, the recommended duration of therapy for acute bacterial pyelonephritis in humans is 7–14 days (Morello *et al*., 2016; Ren *et al*., 2017). There is no reason to suspect that a longer duration would be necessary for dogs and cats. In the absence of veterinary-specific data, the Working Group recommends 10–14 days of treatment.

Subclinical bacteriuria

Treatment of subclinical bacteriuria with antimicrobials is rarely indicated and is discouraged. In animals where it is unclear whether clinical signs are attributable to cystitis, a short course (e.g., 3–5 days duration) of antimicrobials as recommended for sporadic cystitis could be considered. If there is no clinical response, antimicrobials should be discontinued, as an infectious process is unlikely. Treatment of animals with pyuria or other cytological abnormalities without lower urinary tract signs is not recommended (Johnstone, 2020).

The isolation of a multidrug-resistant bacterial species should not affect the decision whether to treat subclinical bacteriuria. Antimicrobial resistance genes are not virulence factors, and resistant organisms are not more likely to cause disease than their susceptible counterparts.

Treatment of subclinical bacteriuria caused by multidrug-resistant pathogens for infection control purposes (e.g., to eliminate urine shedding of a possible pathogen) is not recommended. It is reasonable to assume that the bacterial strain in the bladder is also present in the gastrointestinal tract; therefore, even if bacteria are eliminated from the bladder with antimicrobials, it would likely have limited impact on the overall risk .

In rare circumstances, treatment of subclinical bacteriuria may be considered if there is concern that there is a particularly high risk of ascending or systemic infection or that the bladder may be a focus of extra-urinary infection.

In cases that are unable to display clinical signs of cystitis (e.g., spinal cord injury), a clinical judgment must be made, ensuring that consideration of the need and potential adverse impacts (e.g., adverse drug effects, antimicrobial resistance) are balanced. The relevance of changes in urine appearance and odor (e.g., gross discoloration, malodor) to differentiate infection from subclinical bacteriuria is unclear. However, sometimes a short course of treatment (e.g., 3–5 days duration) could be considered for the quality of life issues if bacteriuria may be playing a role (Johnstone, 2020).

Table 4. Drugs for the management of bacterial urinary tract infection in dogs and cats (Weese *et al.*, 2011).

Drug (WHO category)[a]	Dose	Comments
Amikacin (CIA)	Dogs: 15–30 mg/kg IV/IM/SC every 24 h Cats: 10–14 mg/kg IV/IM/SC every 24 h	Not recommended for routine use but may be useful for treatment of MDR organisms. Potentially nephrotoxic.
Amoxicillin (CIA)	11–15 mg/kg PO every 8–12 h	Good first-line option for sporadic bacterial cystitis. Excreted in urine predominantly in active. *Klebsiella* spp. are resistant. Not recommended for pyelonephritis.
Amoxicillin/clavulanic acid (CIA)	12.5–25 mg/kg PO every 12 h Note: dose of total product (amoxicillin + clavulanic acid)	Reasonable empiric choice for cystitis. Not recommended for pyelonephritis.
Ampicillin (CIA)	N/A	Not recommended because of poor oral bioavailability.
Cefazolin (HIA)	22 mg/kg IV ~30 min prior to the procedure.	Main use is for peri-procedure prophylaxis as a single pre-procedure dose
Cefpodoxime proxetil (HP-CIA)	Dogs: 5–10 mg/kg every 24 h PO days. Cats: no dose established.	More active than cephalexin or cefadroxil against Enterobacteria except *Enterococcus* spp.
Ceftiofur (HP-CIA)	Dogs: 2 mg/kg every 12–24 h SC Cats: no dose established	Approved for treatment of bacterial cystitis in dogs in some regions. *Enterococcus* spp. are resistant.
Cefuroxime (HIA)	Peri-operative prophylaxis: 20–50 mg/kg slow IV	2nd generation cephalosporin that can be used perioperatively. *Enterococcus* are resistant.
Cephalexin, cefadroxil (HIA)	12–25 mg/kg PO every 12 h	Narrow-spectrum activity; not active against Enterobacterials. *Enterococcus* spp. are resistant.
Chloramphenicol (HIA)	Dogs: 40–50 mg/kg PO every 8 h Cats: 12.5–20 mg/kg (to a maximum of 50 mg/cat) PO every 12 h	Reserved for multidrug resistant infections with few other options. Myelosuppression can occur, particularly in cats and with long-term (e.g. >28 days) therapy. Not a first line treatment for pyelonephritis.
Ciprofloxacin (HP-CIA)	25–30 mg/kg PO every 24 h	Sometimes used because of lower cost than fluoroquinolones. Variable oral bioavailability.
Doxycycline (HIA)	5 mg/kg PO every 12 h	Not excreted in urine at high levels but can achieve levels that are effective against some pathogens. Care should be taken with cats to reduce the risk of esophageal ulceration.
Enrofloxacin (HP-CIA)	5–20 mg/kg every 24 h (dogs) 5 mg/kg PO every 24 h (cats)	Excreted in urine predominantly in active form. Reserve for MDR infections but initial/empirical choice for pyelonephritis in dogs. Not recommended for *Enterococcus* spp. It is recommended in cats.
Fosfomycin (CIA)	40 mg/kg PO (with food) every 12 h	Should be reserved for multidrug resistant infections. Do not use in cats. Potential option for pyelonephritis.

Imipenem-cilastatin (CIA)	5 mg/kg IV/IM every 6–8 h	Reserve for treatment of MDR infections, particularly those caused by ESBL-producing *Enterobacterials* or *P. aeruginosa*, while *E. faecium* is inherently resistant.
Levofloxacin (HP-CIA)	25 mg/kg PO every 24 h (dogs)	Sometimes used as a lower cost fluoroquinolone. High oral bioavailability in dogs.
Marbofloxacin (HP-CIA)	2.7–5.5 mg/kg PO every 24 h	Excreted in urine predominantly in active form. Good first line choice for pyelonephritis. Not recommended for *Enterococcus* spp.
Meropenem (CIA)	Dogs: 8.5 mg/kg every 12 h (SC) or every 8 h (IV) Cats: 10 mg/kg every 12 h IV, SC, IM	Reserve for treatment of MDR infections, particularly those caused by ESBL-producing *Enterobacterials* or *P. aeruginosa*, while *E. faecium* is inherently resistant.
Nitrofurantoin (IA)	4.4–5 mg/kg PO every 8 h	Option for sporadic bacterial cystitis, particularly when MDR pathogens are involved. Excreted in urine predominantly in active form.
Orbifloxacin (HP-CIA	Tablets: 2.5–7.5 mg/kg PO every 24 h Suspension (cats): 7.5 mg/kg every 24 h	Reserve for documented MDR but good first choice for pyelonephritis. Not recommended for *Enterococcus* spp.
Pradofloxacin (HP-CIA)	Dogs: 3–5 mg/kg PO every 24 h. Cats: 3–5 mg/kg once daily (tablets) or 5–7.5 mg/kg every 24 h (suspension)	Bacterial cystitis in dogs and cats. Greater activity than older fluoroquinolones. Theoretically a good 1st line choice for pyelonephritis, especially in cats.
Trimethoprim-sulfadiazine/Trimethoprim-sulfamethoxazole/Ormetoprim-sulfadimethoxine (HIA)	15–30 mg/kg PO every 12 h	Appropriate initial or empirical option. Concerns regarding idiosyncratic and immune-mediated adverse effects in some patients; however, this is most relevant with long-term therapy. If prolonged (>7 days) therapy is anticipated. Avoid in dogs that may be sensitive to potential adverse effects such as hepatopathy, hypersensitivity and skin eruptions. Activity against *Enterococcus* spp. in urine is controversial and should be avoided.

HP-CIA: highest priority critically important antimicrobial. CIA: Critically important antimicrobial.
HIA: highly important antimicrobial. IA: Important antimicrobial.
CLSI: Clinical Laboratory Standards Institute. ESBL: Extended spectrum β-lactamase.
a Drug category per World Health Organization guidelines.

Treatment of subclinical bacteriuria caused by plaque-forming (*Corynebacterium urealyticum*) and urease-producing (e.g., *Staphylococci*) organisms could be considered because of their associations with encrusting cystitis and struvite urolith formation, respectively (Biegen *et al*., 2013, Raab *et al*., 2015). Because of the potential difficulties in treating these conditions, consideration of a single short course (3–5 days duration) of treatment, as per 'Sporadic bacterial cystitis,' could be considered after confirming that

bladder wall plaque or uroliths are not present. However, it is unknown whether this is a necessary or effective approach. Continued treatment of subclinical bacteriuria with these strains is likely not warranted.

There is currently no evidence that screening bacterial isolates for urovirulence factors should impact decision-making for subclinical bacteria, as there are currently no data that indicate the isolation of a bacterial strain that possesses urovirulence genes is of greater clinical relevance to an individual patient or that treatment will reduce the risk of disease (Johnstone, 2020).

There is currently no evidence that the use of adjunctive treatments (e.g., cranberry extracts or probiotics) for the prevention of cystitis or subclinical bacteriuria is effective, but there is no contraindication to the use of treatments and supplements that are known to be safe.

If an animal that was recently diagnosed with subclinical bacteriuria subsequently develops signs consistent with cystitis or pyelonephritis, treatment designed to target the organism isolated while clinical signs were absent can be considered. However, the likelihood that a subsequent infection is caused by a previous bacteriuria isolate is not known and probably decreases with time from the last culture. Repeat culture is indicated to determine the optimal treatment if bacteriuria with a multidrug-resistant bacterial species was previously diagnosed. If pyelonephritis is suspected, treatment targeting the previously identified resistant bacterial isolate should be considered, with a plan to de-escalate once culture results are available if a susceptible organism is identified (Johnstone, 2020).

6.3. Antifungal Drugs

Fluconazole is recommended as initial treatment in most cases because of the high margin of safety, sensitivity of most strains of *Candida* spp., and excretion of active drug into urine in high concentrations. On the other side, 19 *Candida* spp. other than *C. albicans* are more likely to be resistant to fluconazole, and antifungal sensitivity testing is recommended to determine if a higher dose of fluconazole is appropriate or if another drug should be used. Although amphotericin B is renally excreted and achieves high concentrations in urine, it is not often used because it is parenterally administered and nephrotoxic (Reagan *et al*., 2019). Other commonly used antifungal drugs, including itraconazole and ketoconazole, are not renally excreted in active form (Hizlisoy *et al*., 2025). Secondary fungal UTI occurs because of shedding of organisms into urine in cases with systemic infections. Organisms most commonly associated with urine shedding are *Aspergillus* spp. in dogs (particularly German shepherd dogs) and *Cryptococcus* spp. in cats. These cases should be treated with antifungal agents standardly recommended for systemic infections (Grassi *et al*., 2024).

6.4. Non Antimicrobial UTIs Therapeutic Approaches

Multidrug-resistant bacterial isolates have significantly increased in recent years as a cause of bacterial UTIs. This increasing resistance to antimicrobial drugs leaves fewer therapeutic options for effective treatment. Urinary tract infections with multidrug-resistant (MDR) bacteria increase morbidity, treatment failures, and therapeutic costs. The emergence of antibiotic-resistant bacteria in the community is necessitating the need to explore non-pharmacologic treatment options to reduce the spread and proliferation of these species (Amphaiphan *et al*., 2021).

Ozone therapy

Ozone is an emerging therapy with both potent antibacterial properties and the ability to modulate the immune system, reduce oxidative stress induced by chronic infection, and upregulate the endogenous antioxidant system, providing further protection from free radical injury.

A 14-year-old female dog, paraplegic, suffered from recurrent bacterial cystitis caused by *Proteus* spp. The case has been treated for two months with enrofloxacin, amoxicillin, and potassium clavulanate. Because of the development of adverse effects such as pharmacodermia and corneal ulcers, the dog was referred to the ozone therapy sector of the Santa Maria Veterinary Hospital, Brazil. The ozone therapy consisted of bladder instillations of ozonized saline solution (O_3SS); (59 µg/mL), once a day for 3 consecutive days. After antisepsis of the external genitalia with 1% chlorhexidine gluconate, a bladder catheterization was performed. Next, within a 20-minute interval, the bladder was washed with 1 L of O_3SS at a concentration of 59 µg/mL. The data extracted from the study proposed removal of the biofilm that covered the bladder mucosa, marked reduction in the suspended echogenic content (sediment), and small hyperechogenic, punctiform, and linear structures suggestive of crystals or small clots. Furthermore, it seemed that O_3SS had changed the pattern of susceptibility to cephalothin and neomycin, which could expand the therapeutic options (Engelmann *et al*., 2023).

Probiotic therapy

Several probiotic bacteria have been proposed as an alternative to combat MDR UTI. Lactic acid bacteria in the genus *Lactobacillus* are some of the most studied and used probiotics (Gupta *et al*., 2024).

L. reuteri KUB-AC5 (AC5), isolated from the chicken gut, has been investigated for both its direct and indirect effects against uropathogenic *E. coli* (UPEC) isolates in vitro using a spot-on lawn, agar-well diffusion, and competitive growth assays. It is found that viable AC5 cells and cell-free components of this probiotic significantly reduced the UPEC growth of all strains tested. The data showed that AC5 can attach to the examined cell line and decrease UPEC attachment in a dose-dependent manner. Pretreatment of UPEC-infected murine macrophage RAW264.7 cells with viable AC5 (multiplicity of infection, MOI = 1) for 24 hours enhanced macrophage-killing activity and increased proinflammatory and anti-inflammatory gene expression. These findings indicate the gut-derived AC5 probiotic could be a potential urogenital probiotic against MDR UTI (Tantibhadrasapa *et al*., 2024).

Snell *et al*. (2022) assessed the in vitro effects of *E. coli* strain Nissle 1917 as a probiotic on UPEC isolated from 40 cats with clinical UTI and subclinical bacteriuria. The results revealed that 52% of isolates were found to be resistant to antimicrobials, with 19% of these being multidrug resistant (MDR). Nissle 1917 adversely affected the growth of 82.5% of all isolates and 100% of MDR isolates in vitro. The median zone of inhibition was 3.33 mm (range, 1.67 to 10.67 mm). Thirteen isolates were affected via competitive overgrowth and 20 via growth inhibition.

The importance of dietary modifications in medical protocols designed to treat and prevent LUTS in pets was postulated. The main goals of dietary modifications to prevent LUTS are 1) promoting large dilute volumes of urine, 2) decreasing the relative supersaturation of urine for specific stone types, and 3) promoting healthy bacterial populations in the gastrointestinal and urogenital tracts. The impact of dietary composition, including dietary moisture, protein concentration and digestibility, mineral concentrations, inclusion of acidifiers and alkalinizing agents, inclusion of vitamin B6, eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and γ-linolenic acid, fiber concentration and characteristics, and oxalate degrading probiotics (Kerr, 2013).

Bacteriophage

A study evaluated the therapeutic efficacy of phage P2-71 against *P. mirabilis,* "a particular urinary tract pathogen," in vivo and in vitro environments. The results demonstrated that in vitro, bacteriophage P2-71 achieved significant reductions in *P. mirabilis* concentrations, with log reductions of 1.537 and 0.7009 CFU/mL in laboratory and urine environments, respectively ($p < 0.001$). The phage also decreased biofilm formation by 34-49% and lysed 15-25% of mature biofilms at various multiplicities of infection (MOIs) ($p < 0.001$). In vivo, phage treatment significantly lowered bacterial concentrations in the urine on Days 1 and 3 ($p < 0.0001$), achieving a maximum reduction of 4.602 $\log_{10}$ CFU/mL; however, its effectiveness diminished by Day 5 ($p > 0.05$). Concurrently, phage titers decreased over time. Importantly, phage treatment notably reduced bacterial load in the bladder, kidneys, and spleen ($p < 0.001$). Inflammatory markers such as IL-6, IL-1β, and TNF-α were significantly lower in the treatment group, especially in the bladder ($p < 0.0001$), indicating an effective reduction in inflammation. So it was concluded that bacteriophage P2-71 is a promising alternative therapy for UTIs caused by MDR *Proteus mirabilis* (Wu *et al*., 2024).

6.5. Ancillary Therapies and Prevention

Methenamine

Methenamine salt is a urinary antiseptic that is converted to bacteriostatic formaldehyde in an acidic environment (urine pH <5.5). There is controversy in human medicine as to whether methenamine prevents UTI, although there is some evidence that it may be effective for short-term prophylaxis. It is unknown if the 2 salts described in the literature, hippurate and mandelate, are equally effective; the mandelate salt is difficult to find. There is limited veterinary literature on the use of methenamine in small animals, although there is a theoretic benefit. Studies of safety, efficacy, and appropriate dosing are lacking. Commonly recommended doses are 10 to 20 mg/kg orally every 12 hours (dog) and 250 mg per cat orally every 12 hours. Gastrointestinal upset and dysuria are the most commonly reported adverse events; methenamine is poorly tolerated by feline patients. Methenamine should not be used in cases of renal failure. Concurrent use of a urinary acidifier, such as dl-methionine, is usually required for maximal effect (Weese *et al*., 2011).

Cranberry

Proanthocyanidin, the "active ingredient" in cranberry, alters the genotypic or phenotypic expression of fimbriae, which subsequently inhibits *E. coli* adherence to human bladder and vaginal epithelial cells. There are few veterinary studies in healthy dogs and no feline studies. In addition, quality and potency are variable among over-the-counter products; ideally, each formulation would be tested in the species of interest. The consensus of the Antimicrobial Guidelines Working Group of the International Society for Companion Animal Infectious Diseases is that there is insufficient evidence to support the use of cranberry extract to prevent recurrent UTIs in dogs and cats (Weese *et al*., 2011).

Anti-biofilms

Some bacteria have the capacity for biofilm formation, which facilitates colonization. A biofilm is composed of organisms adhered together by a self-produced polysaccharide matrix. It has been suggested that the bacteria within the biofilm become sessile; they are protected from the immune system, are antimicrobial, and inherently are resistant to shear forces of removal. Biofilms are also implemented in the development of catheter-associated UTIs.

Strategies to prevent catheter-associated biofilms include using (1) materials that are less amendable to biofilm formation and (2) coatings or surface modifications that decrease biofilm formation. For example, silicone catheters are preferred over latex because scanning electron microscope imaging reveals that latex surfaces are more irregular and promote microbial adherence (Olin and Bartges 2015). In a veterinary prospective study (n = 26 dogs) evaluating biofilm formation on indwelling urinary catheters, sustained-release varnish of chlorhexidine-coated urinary catheters statistically decreased biofilm formation (Segev *et al*., 2013). There are an array of other catheter coatings and modifications to decrease bacterial adherence and biofilm formation that have primarily been studied in a research setting, including silver coating, nanoparticles, iontophoresis, antimicrobials, urease and other enzyme inhibitors, liposomes, and bacteriophages. Other novel strategies include quorum sensing inhibitors and vibroacoustic stimulation (Siddiq and Darouiche, 2012).

Vaccination

Vaccination is the most logical way to try and control infection and reduce the prevalence of clinical disease and shedding. Bivalent vaccines containing the serogroups *L. icterohaemorrhagiae* and *L. canicola* have been in widespread use for many years, and infection with *L. canicola* is now uncommon based upon the MAT. Leptospirosis has been reported in dogs in Europe vaccinated with bivalent vaccines. Quadrivalent leptospirosis vaccines, targeting *L. canicola*, *L. icterohaemorrhagiae*, *L. pomona,* and *L. grippotyphosa*, were introduced in the USA in 2001 and are now available in Europe. The current European vaccines contain either three serogroups (*L. canicola*, *L. icterohaemorrhagiae*, and *L. grippotyphosa*) or four serogroups (*L. canicola*, *L. icterohaemorrhagiae*, *L. grippotyphosa,* and *L. bratislava*). The European consensus statement recommends the use of quadrivalent vaccines (Murphy, 2018).

Vaccination is recommended as soon as clinical recovery is seen. There have been concerns raised about reactions to quadrivalent vaccines and about reactions to leptospirosis vaccination, particularly in small dogs. Veterinarians should report any suspected adverse

drug reactions to the authorities to increase the evidence available to confirm or refute these claims. Current literature does not show vaccines with leptospiral antigen to be associated with more significant reactions than other vaccines (Murphy, 2018). There is no commercial vaccine available for cats. However, one study has shown that cats can produce antibodies (of lower titre magnitude than vaccinated dogs) when experimentally inoculated with a commercial dog vaccine (containing four different serovars). The follow-up time for the animals was 42 days, at which point only one animal maintained antibody levels. The authors of that study suggest further work is needed before a vaccine against *Leptospira* species for cats can be considered. Given the current lack of a vaccine, the best way to avoid infection in cats is via prevention of exposure. Cats that are kept indoors have a lower risk of being infected. Prevention of predation opportunities and avoidance of contact with stagnant water, urine from infected animals, and dogs at risk of clinical leptospirosis is recommended. For cats that share an environment with a positively diagnosed animal, doxycycline can be given at 5 mg/kg PO q12h or at 10 mg/kg PO q24h for 2 weeks. 19,60 **(Murillo *et al*., 2020)**.

TRANSMISSION OF UROPATHOGENS BETWEEN HUMANS AND PETS: A PUBLIC HEALTH IMPORTANCE

Since the close relationship and direct contact between humans and pets, the potential for transmission of antimicrobial resistant bacteria or their resistance determinants from companion animals to vulnerable populations, especially children and immunocompromised persons, poses a public health concern (Amphaiphan *et al*., 2021). Given the possibility of zoonotic transmission of antimicrobial-resistant bacteria, veterinarians, when treating UTI cases, should inform pet owners of the potential transmission risk (Yudhanto *et al*., 2022). Often, major urinary bacterial pathogens of dogs can be resistant to antimicrobials commonly used to treat UTIs or to antimicrobials important for human medicine. Previous studies described resistance to carbapenems in *E. coli* isolates that have carried the carbapenem resistance gene blaNDM-5. Carbapenems are critically important antibiotics used to treat serious bacterial infections in humans and are considered one of the human use last resorts (Tyson *et al*., 2019). A recent study in Egypt declared the prevalence of shared UPEC serotypes isolated from companion animals and humans, as well as sharing in the presence of virulence determinants and the blaNDM-1 gene, which is responsible for carbapenem resistance, proposing a potential public health concern (Hakim *et al*., 2024a). In Australia, there is a particular significance with the detection of the human UTI pandemic MDR *E. coli* strain O25b:H4-ST131 in dogs. The significantly higher prevalence of this clonal lineage among fluoroquinolone-resistant *E. coli* isolates from humans compared to dogs suggests that human-to-dog transmission may currently predominate (Johnstone, 2020).

Similarly, resistance to fluoroquinolones in *Pseudomonas aeruginosa* isolates has been mentioned (Harada *et al*., 2012) and against cephalosporins (Hakim *et al*., 2024b). Also, an increase in MDR methicillin-resistant *Staphylococcus pseudintermedius* (MRSP) isolated from dogs with UTI has been reported (Grönthal *et al*., 2017; Smith *et al*., 2020b).

The zoonosis, leptospirosis, is caused by pathogenic spirochetes of the genus *Leptospira,* which colonize the renal tubules where they reproduce before being excreted via the urine. Infected urine or contaminated water are sources of leptospirosis infection; asymptomatic and chronic carrier dogs can be maintenance hosts, acting as sources of infection and therefore causing a public health problem. Formerly, it was thought that domestic cats were resistant to leptospirosis infection; however, recently published reports on feline leptospirosis conclude that cats may play a role in the epidemiology of this disease (Donato *et al*., 2022).

CONCLUSION

The illnesses of the urinary tract in small animal, particularly in dogs and cats, occur frequently with different etiologies. Many factors can predispose pets to UTIs, including bladder stones, diabetes mellitus, anatomical abnormalities, and weakened immune systems. The most common causes of UTIs are bacteria that go upwards through the urethral opening. Bacterial UTIs are reported to occur in about 14% of all dogs at some time during their lives, and the infection rate was higher in females compared to males because of differences in anatomy. The infection rate was highest in dogs younger than 2 years and older than 6 years, reaching 50% in females older than 10 years. Due to their cleanliness and high urine osmolarity, cats have a lower prevalence. The UTIs in dogs and cats are caused by *E. coli*, *P. aeruginosa*, *Klebsiella* spp., *Proteus* spp., *Staphylococcus* spp., *Streptococcus* spp., and *Enterococci*. In addition to bacteria, fungi or viruses may also infect the urinary tracts. Cystocentesis is the proper aseptic urine sampling for culture diagnostics. Diagnosis is based on microbial culture as a gold standard method, besides direct microscopy examination of urine sediment, biochemical examinations, urinalysis, serological, and molecular techniques used for species identification. The foundation of effective treatment is the disc-diffusion method, which determines a pathogen's susceptibility to antibiotics; however, the serial dilution technique is more precise. Use of empirical antibiotics is substantial as they affect the most likely bacteria causing infection. In most cases, amoxicillin, amoxicillin-clavulanic acid, and trimethoprim-sulfonamides are considered the first empirical antimicrobial choices for UTI treatment in pets. The increasing resistance to antimicrobial drugs leaves scarce therapeutic choices for effective treatment. The emergence of MDR elevates the need to explore non-pharmacologic treatment options such as ozone therapy, probiotics, bacteriophage, herbs, and nutrient supplements. The increased incidence of MDR bacteria represents a potential cause of antibiotic failure in companion animals and constitutes a serious threat to global public health due to the presence of potentially zoonotic microbial reservoirs in pet animals.

RECOMMENDATION

Urinary tract infections are a common issue in both dogs and cats, and it's essential to understand how they're approached. Here's a breakdown of key recommendations:

*Veterinary Consultation: If you suspect your pet has a UTI, seek veterinary care immediately.

*Accurate Diagnosis: Ensure your veterinarian performs a urinalysis and, ideally, a urine culture and sensitivity test.

*Follow Veterinary Instructions: Adhere strictly to your veterinarian's treatment plan, including completing the full course of antibiotics.

*Preventative Measures: Provide plenty of fresh water and maintain a clean litter box for cats.

*Advise vet. clinicians and vet. Lab specialists about the importance of conducting bacterial culture and AST before starting UTI treatment to prevent the emergence of MDR bacteria.

*Since pets could become the reservoirs of MDR bacteria that may be transmitted to humans, veterinarians should inform pets' owners about the potential zoonotic transmission risk of these pathogens.

*Continuous monitoring of the AMR patterns of clinically important bacterial urinary pathogens is warranted to identify emerging MDR strains.

*Monitoring the antibiotic resistance profiles in pet infections is important not only for the public health implications but also to collect data useful for the treatment of diseases in pets.

*To obtain information useful for global plans aimed at fighting AMR, surveillance and rapid identification of AMR infections in pets have been highlighted within the framework of the One Health approach, which recognizes that the health of people is closely connected to the health of animals and the shared environment.

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