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Hospital-acquired catheter-associated urinary tract infections in critical care unit dogs with high rates of multidrug-resistant organisms

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ABSTRACT

Background: Urethral catheterization in the critical care unit often compromises the urinary tract's defense mechanisms of canine patients and potentially leads to hospital-acquired systemic infection. Clinical signs of hospital-acquired catheter-associated urinary tract infections (CAUTIs) are frequently absent in critical dogs.

Aim: This study aimed to evaluate the correlation between urinalysis results and CAUTIs in critical care unit dogs and assess the impact of prior antibiotic treatment for underlying diseases and antibiotic-resistant bacteria.

Methods: Twenty-eight dogs underwent urethral catheterization in the critical care unit of Kasetsart University Veterinary Teaching Hospital. Bacterial cultures and drug sensitivity tests were performed immediately after catheter placement (day 0), 3, and 7 and before removal. A positive urine culture was defined as $\geq 10^4$ CFU/ml. Urinalysis parameters included urine pH, urinary specific gravity, proteinuria, bacteriuria, pyuria, and hematuria. Only dogs with culture-negative results on day 0 were included. Data were analyzed using GraphPad Prism version 10.0.2. A Kaplan–Meier survival analysis was used to assess the probability of being free from CAUTIs over time.

Results: No significant association was observed between urine cultures and urinalysis parameters, catheterization duration, breed, sex, neutering status, or age. Dogs pretreated with antibiotics exhibited CAUTI-free periods longer than previously reported. The Kaplan–Meier analysis showed that CAUTI-free probabilities were 92.8% at 3 days, declining to 60.7% by 7 days and 53.6% at 10 days. Alarmingly, 80% of the isolates (12/15) were multidrug-resistant organisms (MDRO) resistant to ≥3 antimicrobials. A high incidence of hospital-acquired CAUTIs was detected in 13 of 28 cases (46.4%). The dogs with CAUTIs stayed longer in the hospital than dogs without CAUTIs.

Conclusion: A routine urinalysis is unreliable for predicting hospital-acquired CAUTIs. The high rate of MDRO among critical care dogs underscores the urgent need for judicious antibiotic use and the need for enhanced diagnostic methods in critical care settings. This study proposes that serial bacterial cultures combined with modified urine sediment examinations can better manage CAUTI detection and reduce the growth of MDROs in veterinary practice.

Keywords: Hospital-acquired infection, Catheter-associated urinary tract infection, Urinalysis, Canine patients, Critical care unit.

Introduction

Urethral catheterization is a common canine procedure. Several natural defense mechanisms prevent urinary tract infection (UTI), normal micturition, anatomical structures, mucosal defense barriers, urine antimicrobial properties, and systemic immunocompetence (Ettinger *et al.*, 2017). However, urinary catheter placement frequently compromises these defense mechanisms, thereby introducing bacteria into the urinary tract during

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the procedure. This condition could lead to bacterial colonization and systemic infection (sepsis) caused by ascending infection to the kidneys (Segev *et al.*, 2013; Weese *et al.*, 2019). The prevalence of bacteriuria in catheterized dogs and cats is high (Segev *et al.*, 2013; Weese *et al.*, 2019). UTIs are among the most common healthcare-associated infections (HAIs) in humans, resulting in significant morbidity increased health care costs, and, occasionally, mortality. Similarly, catheter-associated UTIs are among the most common HAIs in small animal veterinary medicine, occurring in 10%–32% of hospitalized dogs (Stull and Weese, 2015).

The clinical signs of UTI are often absent in catheterized patients, even when urine bacterial culture yields positive results (Schwartz and Barone, 2006). Urinalysis is routinely performed to assess catheter-associated urinary tract inflammation. However, its ability to predict UTIs remains contentious (Schwartz and Barone, 2006). Additionally, in catheterized patients, pyuria is not an indicator of catheter-associated bacteriuria or catheter-associated urinary tract infections (CAUTIs) (Hooton *et al.*, 2010; Saran *et al.*, 2018).

Antimicrobials are commonly prescribed to dogs in the critical care unit with suspected infections without confirmed bacterial culture. Blood culture failed to detect bacterial sepsis in critical care unit dogs with pyrexia of unknown origin. There is only 20% yielded bacteria growth from blood culture (Saarenkari *et al.*, 2022).

The duration of catheterization is the most significant risk factor for infection. Therefore, catheterization should be as short as possible (Weese *et al.*, 2019). Each additional day of catheterization increases the incidence of UTI by 27% (Bubenik *et al.*, 2007). A previous study reported that placing an indwelling urinary catheter in dogs is associated with a low risk of catheter-associated UTI during the first 3 days after catheter placement (Smarick *et al.*, 2004).

Prophylactic antimicrobial therapy for the prevention of catheter-associated bacterial cystitis is not indicated (Bubenik *et al.*, 2007; Weese *et al.*, 2019). One study showed that administering antimicrobials increased the likelihood of UTI by 454% in catheterized dogs (Bubenik *et al.*, 2007). Additionally, other studies have found that administering antimicrobials during catheterization leads to the occurrence of more antimicrobial-resistant bacteria (Lees and Osborne, 1980; Barsanti *et al.*, 1985). The rise of antimicrobial resistance is a growing concern in both small animal medicine and human health. Increasing resistance among canine pathogens complicates treatment and poses a public health risk, especially when the pathogens are zoonotic or when resistance genes can transfer between bacteria of animal and human origin (Guardabassi *et al.*, 2004; Windahl *et al.*, 2014; Wong *et al.*, 2015; Cooke *et al.*, 2022). Conversely, there is debate over whether a single antibiotic dose can delay biofilm development for up to 4 days (Koseoglu *et al.*, 2006).

Multidrug-resistant organisms (MDROs) are bacteria that develop resistance to multiple antibiotics, significantly diminishing the effectiveness of antimicrobial treatment. The spread of MDROs is now considered one of the most critical public health threats, contributing to increased rates of illness, death, higher healthcare costs, and excessive antibiotic use (Duin and Paterson, 2016; Serra-Burriel *et al.*, 2020; Antimicrobial Resistance Collaborators, 2022). A retrospective study analyzed 278 patients with community-acquired MDRO-associated UTIs (Bian *et al.*, 2024). The current study found that MDRO-associated UTIs primarily occurred in elderly, frail patients with a history of invasive urinary tract procedures, thereby imposing a more significant economic burden compared with non-MDRO UTIs.

There are only a few studies on the occurrence of hospital-acquired CAUTIs in critical care unit dogs. This study aimed to investigate the occurrence of hospital-acquired CAUTIs among dogs in the critical care unit, assess urinalysis parameters for predicting CAUTIs, identify possible associated factors, and identify causative bacteria and patterns of antimicrobial resistance.

Materials and Methods

For the placement of a urinary catheter, the area around the vulva or preputial opening was clipped of hair and then prepared with a chlorhexidine scrub. Subsequently, an appropriately sized silicone-coated latex Foley catheter for female dogs and a silicone Foley catheter for male dogs were inserted into the bladder using sterile gloves and lubricant. Immediately after placement, baseline urine samples (Day 0) were collected via the urinary catheter for urinalysis, aerobic bacterial culture, and drug sensitivity testing. A sterile closed collection system was promptly connected to the catheter following placement. Urinary catheters were regularly inspected to detect any issues that could increase the risk of infection, such as breakage or gross fecal contamination. The exposed portion of the catheter was then cleaned with a chlorhexidine solution, and the vulvar or preputial area was also cleaned and flushed with chlorhexidine solution. Urine was aseptically collected from the drainage port of the urinary catheter on days 3 and 7 postplacement and before removal, and then aseptically transferred via a syringe into a sterile tube containing no preservative. Subsequently, urine samples were subjected to urinalysis, aerobic bacterial culture, and drug sensitivity testing within 1 hour of collection.

Urinalysis was performed by dipstick analysis, urine sediment evaluation, and measurement of urinary specific gravity using a refractometer. Pyuria (white blood cell count >5 cells/HPF), hematuria (red blood cell count >5 cells/HPF), proteinuria, and bacteriuria were recorded.

Aerobic bacteria from urine were cultured on MacConkey and 5% sheep blood agar plates (Merck,

Darmstadt, Germany) and incubated at 37°C for 24–48 hours under aerobic conditions (Quinn *et al.*, 2011). Colony counts were conducted on all urine samples showing growth. A positive urine culture was defined as a culture with isolation of $>10^4$ CFU/ml from the urinary catheter of an identified pathogen (Elliott *et al.*, 2017). Bacterial isolates were tested for susceptibility to antimicrobials based on bacterial genera and species. Microbial isolates were identified using routine biochemical and automated systems (VI-TEK 2 COMPACT; Biomerieux). Susceptibility testing for antibacterial agents was performed on Mueller–Hinton agar using antimicrobial disks (MASTDISC® AST; England). The antibiotics included in the testing were amikacin, amoxicillin, amoxicillin/clavulanic acid, azithromycin, ceftriaxone, cephalexin, ciprofloxacin, enrofloxacin, gentamicin, imipenem, marbofloxacin, meropenem, norfloxacin, nitrofurantoin, sulfamethoxazole-trimethoprim, and vancomycin. A bacterial isolate was classified as multidrug-resistant (MDR) if it demonstrated intermediate susceptibility or resistance to three or more antimicrobial classes (Magiorakos *et al.*, 2012). Dogs with a positive urine culture result, pyuria, or bacteriuria prior to catheter placement will be excluded from the study.

Data were analyzed using GraphPad Prism version 10.0.2 software (GraphPad Software, Inc.; La Jolla, CA). The Kaplan–Meier survival analysis was used to assess the probability of being free from UTI over time. A dog was considered free from UTI on the day of the first urine sample yielding positive bacterial culture results. The Cox proportional hazard test and Fisher's exact test were used to examine associations between individual breeds and all breeds, sex, neutering status, age, duration of catheterization, urinalysis parameters, and the rate of UTI. Univariate Cox regression analyses were performed with a p-value ≤ 0.2. The final model was analyzed by backward stepwise selection. The Mann–Whitney U test was used to compare the duration of hospitalization between the culture-positive and culture-negative groups. The significance level was set at 0.05. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were analyzed between a reference standard tool, urine bacterial cultures, and bacteriuria by microscopic examination of the urine sediment using the NCSS 2023 program version 23.0.1.

Ethical approval

This prospective study was conducted at the Kasetsart University Veterinary Teaching Hospital in Bangkok, Thailand. Dogs hospitalized in the intensive and critical care units between March 2023 and 2024, undergoing urinary catheter placement either upon admission or during hospitalization, will be included in the study. Ethical approval was obtained from the Kasetsart University Institutional Animal Care and Use Committee (ACKU66-VET-016), and owner consent was obtained. Information obtained from each dog enrolled in the study included the dog's vital signs, disease status, antimicrobials administered, and the duration of urinary catheterization.

Results

Thirty-two dogs were initially included in the study. Two dogs were excluded due to positive urine culture results, whereas each one exhibited pyuria and bacteriuria. Subsequently, 28 dogs were enrolled in the study. There were 3 males (2 sexually intact and 1 neutered) and 25 females (6 sexually intact and 19 spayed). The median age was 5 years (range, 2–17 years), and the median weight was 12.05 kg (range, 3.25–36.3 kg). The most common breeds were crossbreed (9/28 [32.1%]), French Bulldog (4/28 [14.3%]), and Thai Bangkaew (3/28 [10.7%]). Other represented breeds included two dogs each of Pomeranian, Poodle, Shih Tzu, Siberian Husky, and Welsh Corgi, and one dog each of Chihuahua and Golden Retriever (Table S1).

For disease history, the following conditions were assessed: closed pyometra, vector-borne diseases, pneumonia, pancreatitis, hepatic mass, acute kidney injury, canine distemper virus infection, encephalitis, diabetes mellitus, postoperative cases, lymphoma, cholangiohepatitis, and hemorrhagic gastroenteritis (Table S1).

In the history of administration of antimicrobials, nine dogs received a single antibiotic: amoxicillin/clavulanic acid (8 dogs) and imipenem (1 dog). Eighteen dogs received combinations of two antibiotics, imipenem and metronidazole (4 dogs), amoxicillin/clavulanic acid and metronidazole (3 dogs), amoxicillin/clavulanic acid and azithromycin (2 dogs), amoxicillin/clavulanic acid and doxycycline (2 dogs), imipenem and doxycycline (2 dogs), imipenem and sulfamethoxazole-trimethoprim (1 dog), imipenem and azithromycin (1 dogs), doxycycline and clindamycin (1 dog), doxycycline and marbofloxacin (1 dog), and metronidazole and enrofloxacin (1 dog). Additionally, one dog received three antibiotics: imipenem, metronidazole, and tylosin (Table S1).

The median duration of urinary catheterization for 28 dogs was 6 days (range, 2–16 days). The bacterial culture of urine samples resulted in the growth of at least one species in 13 of 28 cases (46.4%). Among these, two dogs showed positive urine culture on day 3 (2/13; 15.4%), three dogs on day 4 (3/13; 23%), one dog on day 6 (1/13; 7.7%), five dogs on day 7 (5/13; 38.5%), and two dogs on day 10 (2/13; 15.4%). The median catheterization and hospitalization duration in the urine culture-positive group was 7 days (4–16 days). Fifteen dogs had urine culture-negative results until catheter removal. The median duration of catheterization and hospitalization in the urine culture-negative group was 4 days (2–12 days). According to the Kaplan–Meier survival analysis, the probability of being free from UTI after 3 days was 92.8%, which decreased to 60.7% after 7 days and 53.6% after 10 days (Fig. 1). The Mann–Whitney U test revealed that the duration of hospitalization was significantly

longer in the culture-positive group than in the culture-negative group (p-value = 0.0025) (Fig. 2).

Twelve dogs had single bacterial growth: 6 had *Enterococcus faecalis*, 2 had *Escherichia coli*, 2 had *Acinetobacter* spp., and one had *Klebsiella pneumonia* and *Pseudomonas aeruginosa*. Additionally, one dog showed growth of three bacterial species: *E. coli*, *K. pneumoniae*, and *P. aeruginosa*. The drug sensitivity test results for all samples are shown in Table 1. Fifteen bacterial isolates were obtained from 12 dogs. Eighty percent of the isolates were classified as MDRO, resistant to ≥3 antimicrobials, and the distribution of pathogens resistant to MDR is shown in Table 2. *Enterococcus faecalis* was the most common MDR isolates.

No statistical association was found between positive or negative urine culture results and breed, sex, neutering status, age, duration of catheterization, and all urinalysis parameters, as determined by the Cox proportional hazards test and Fisher's exact test.

In the univariate Cox proportional hazards test, a significant association was found between UTI and bacteriuria and between UTI and age >7 years. However, the multivariate analysis found no significant association between UTI and bacteriuria or age >7 years (p-value = 0.087, p-value = 0.093, respectively; 95% confidence interval).

A comparison of the bacteriuria results with the urine bacterial cultures is presented in Table 3. The sensitivity of bacteriuria was 38.46% (95% CI; 8.17%–68.75%). The specificity of bacteriuria was 93.33% (95% CI; 77.38%–100%). The positive and NPV were 83.33% (95% CI; 45.18%–100%) and 63.64% (95% CI; 41.26–86.01), respectively.

Discussion

The incidence of hospital-acquired CAUTIs in the critical care unit dogs in this study was 46.4% (13 of 28 cases), a figure that requires immediate attention. This high incidence, which is significantly higher than that reported in other studies (Smarick *et al.*, 2004; Ogeer-Gyles *et al.*, 2006), is likely due to the longer median duration of catheterization (6 days; range: 2–16 days). Previous studies have reported that the duration of catheterization is one of the significant risk factors for catheter-associated UTI, which is likely to significantly increase with the duration of catheterization by 27% for each day of catheterization (Bubenik *et al.*, 2007). This retrospective study of human patients with MDRO-associated UTIs found that the independent risk factors for these infections included high white blood cell

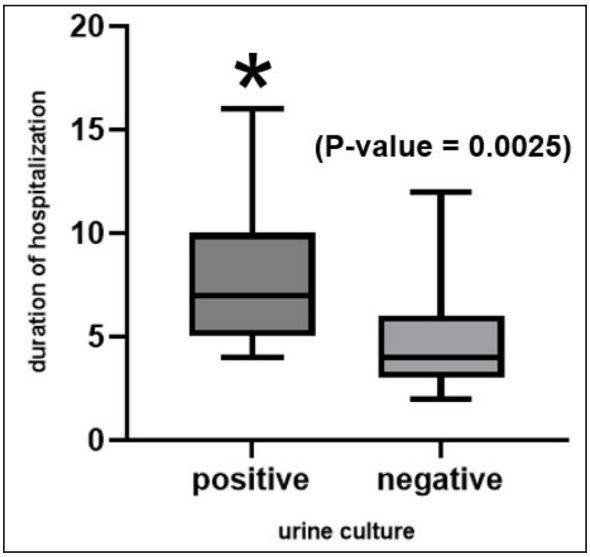

Fig. 2. Box and whisker plot showing the duration of hospitalization for dogs in the culture-positive and culture-negative groups.

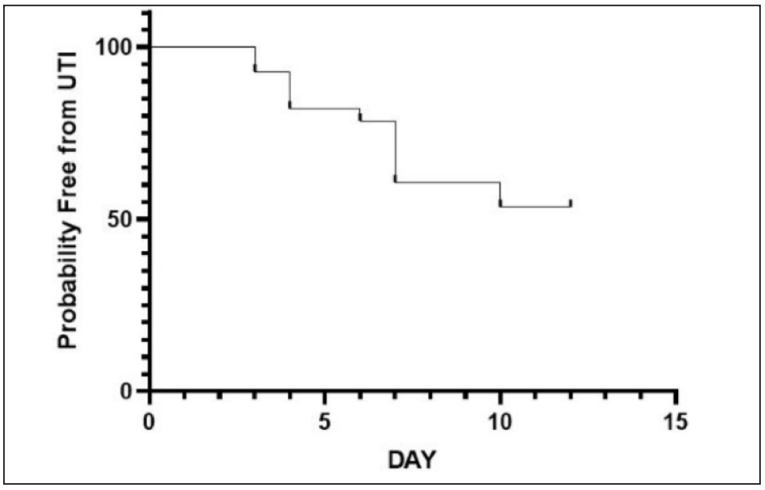

Fig. 1. Kaplan–Meier plot of the probability of being free from CAUTI over time.

Table 1. Antimicrobial susceptibility (%) of all positive urine culture samples.

Antimicrobial	*Acinetobacter* spp. (*n* = 2)	*Enterococcus faecalis* (*n* = 6)	*Eschericia coli* (*n* = 3)	*Klebsiella pneumoniae* (*n* = 2)	*Pseudomonas aeruginosa* (*n* = 2)
Amikacin	50	0	67	50	100
Amoxicillin	0	0	33	0	NA
Amoxicillin/ Clavulanic Acid	0	0	33	0	NA
Azithromycin	0	0	33	0	NA
Ceftriaxone	0	0	33	0	NA
Cephalexin	0	0	33	0	NA
Ciprofloxacin	0	0	33	0	100
Enrofloxacin	0	0	0	0	50
Gentamicin	0	0	33	0	100
Imipenem	0	0	100	50	100
Marbofloxacin	0	0	33	0	100
Meropenem	0	0	100	50	100
Norfloxacin	0	0	33	0	100
Nitrofurantoin	NA	0	NA	0	NA
Sulfa-Trimethoprim	0	0	67	0	NA
Vancomycin	NA	100	NA	0	NA

Table 2. Distribution of pathogens according to MDR and non-MDR groups.

Bacterial isolates (15)	MDR	Non-MDR
Acinetobacter spp. (*n* = 2)	2	0
Enterococcus faecalis (*n* = 6)	6	0
Escherichia coli (*n* = 3)	2	1
Klebsiella pneumoniae (*n* = 2)	2	0
P. aeruginosa (*n* = 2)	0	2
	12 (80%)	3 (20%)

Table 3. Diagnostic assessment of bacteriuria by microscopic examination of urine sediment compared with urine bacterial culture results.

Diagnostic assessment	Bacteriuria (95%CI)
Sensitivity (%)	38.46 (8.17–68.75)
Specificity (%)	93.33 (77.38–100)
PPV (%)	83.33 (45.18–100)
NPV (%)	63.64 (41.26–86.01)

CI = confidence interval.

counts, multiple urinary tract obstructive diseases, use of third-generation cephalosporins, and a history of invasive urologic procedures. The MDRO group also exhibited longer hospital stays, more antibiotic use, and increased bladder catheter use (Bian *et al.*, 2024). CAUTIs are among the most common HAIs in small animal veterinary medicine (Stull and Weese, 2015). Patients with these conditions are often caused by MDROs, complicating treatment and potentially leading to prolonged hospitalization, higher costs, and worse outcomes. The duration of hospitalization was significantly longer in dogs with CAUTIs than in the urine culture-negative group.

In this study, the probability of remaining free from UTI after 3 days was 92.8%, which decreased to 60.7% after 7 days and 53.6% after 10 days. A longer duration was observed compared with another study in which the probability of remaining free from UTI decreased to 63.3% by day 4 (Smarick *et al.*, 2004), possibly due to antibiotic use in every dog in our study. Another study suggested that a single dose of antibiotic, especially a higher-generation antibiotic (Koseoglu *et al.*, 2006), can delay UTI onset and reduce the likelihood of UTI development compared with dogs that do not receive antimicrobials (Smarick *et al.*, 2004). However, it cannot prevent hospital-associated CAUTIs and may lead to antimicrobial resistance. Additionally, this study found a delay in UTI onset but identified pathogens with MDR in 13 of 15 isolates (80%). The findings from this study provide strong scientific evidence that improves the reliability of the information recommended in the guidelines for diagnosing and managing bacterial UTIs in dogs and cats (Weese *et al.*, 2019). These guidelines state

that prophylactic antimicrobial therapy for the prevention of cystitis in catheterized animals is not indicated, and the duration of catheterization should be as short as possible.

One possible reason for systemic antimicrobial administration's failure to prevent catheter-associated UTIs is biofilm formation. After a catheter is placed and comes in contact with urine, a conditioning film forms due to the deposition of host-derived factors. The surface provides binding sites for bacterial colonization, leading to biofilm formation and maturation. Bacteria within biofilms decrease susceptibility to antimicrobials (Trautner and Darouiche, 2004; Koseoglu *et al.*, 2006; Shapur *et al.*, 2012; Segev *et al.*, 2013).

Widespread antimicrobial resistance is an emerging problem in small animal medicine and human health. The close contact between pets and humans creates favorable conditions for the transmission of bacteria, either through direct contact or via the domestic environment. The transmission of antimicrobial-resistant bacteria from pets to humans is particularly concerning when strains carry resistance genes relevant to human medicine. There is a risk that resistant bacteria and/or resistance genes could be transferred from pets to humans, including bacterial species and resistance genotypes of clinical significance (Cooke *et al.*, 2002; Guardabassi *et al.*,2004; Windahl *et al.*, 2014; Wong *et al.*, 2015).

In recent years, MDROs have become a significant concern in veterinary practice, mirroring trends observed in human health care. The increasing use of antibiotics in companion animals and livestock has contributed to the development of resistance, particularly in critical care settings where prolonged or broad-spectrum antibiotic use is common. Pathogens, such as *E. coli*, *Staphylococcus pseudintermedius*, and *P. aeruginosa,* have been frequently implicated in infections that are difficult to treat due to resistance to multiple antimicrobial classes (Guardabassi *et al.*,2004; Weese *et al.*, 2019). In veterinary hospitals, MDROs pose challenges in treating infections such as UTIs, post-surgical wound infections, and respiratory diseases, often requiring advanced diagnostic approaches and limited therapeutic options (Lloyd, 2007).

HAIs are a growing concern in veterinary settings, particularly in critical care units where animals are more vulnerable due to compromised immune systems and invasive procedures, such as catheterization, mechanical ventilation, and surgery (Sykes, 2014). Common pathogens in veterinary HAIs include *S. pseudintermedius*, *E. coli*, and *P. aeruginosa*, many of which exhibit MDR (Walther *et al.*, 2017). In critical care units, prolonged patient stay and increased use of medical devices further elevate the risk of infection. Preventing HAIs in these settings requires rigorous infection control protocols, including proper hand hygiene, equipment sterilization, and animal isolation (Sykes, 2014). Despite these measures, HAIs remain a significant issue, leading to prolonged hospitalization, increased costs, and, in severe cases, increased mortality (Stull and Weese , 2015). The rise of MDROs in these settings further complicates treatment, emphasizing the need for ongoing surveillance and antimicrobial stewardship programs to mitigate the risk of HAIs. However, veterinary-specific data on CAUTIs are limited. Research in this area is essential for improving infection control protocols and patient care in critical veterinary care settings.

Microscopic examination of urine sediment can generally assist in diagnosing UTIs, but no urinalysis parameters in this study were able to predict catheter-associated UTIs. One study found that light microscopic examination of specimens stained with modified Wright's stain is more sensitive and specific than examination of routine unstained preparations. The sensitivity and specificity were 93.2%, 99.0% and 82.4%, 76.4%, respectively, compared with urine culture results (Swenson *et al.*, 2004). The prevalence of positive aerobic bacterial urine culture in dogs with inactive urine sediment is low (3.4%) (Strachan *et al.*, 2022). Therefore, urine sediment examination could help identify specimens that are likely to yield positive culture results. Although bacteriuria was likely associated with UTIs in our study, the relationship was not statistically significant. Therefore, modified Wright's staining may provide a more sensitive and specific prediction of catheter-associated UTI and should be considered.

Age may be a risk factor for developing catheter-associated UTIs but this factor was not found to be significant in this study. A previous study reported that each additional year of age increases the risk of developing a UTI by 20% (Bubenik *et al.*, 2007). This increased risk may be attributed to age-related changes in the immune system (Graham *et al.*, 2006). In older dogs, urinary catheterization compromises the normal defense mechanisms, and the altered immune response associated with aging may contribute to the development of UTIs.

To the best of our knowledge, there is no effective prevention method for catheter-associated UTIs. However, future research can find a solution. Urinary catheters coated with antibacterial substances, such as silver or chlorhexidine, have shown potential in reducing bacterial colonization and biofilm formation (Shapur *et al.*, 2012; Segev *et al.*, 2013; Gefter Shenderovich *et al.*, 2018; Srisang *et al.*, 2019; Srisang and Nasongkla, 2019a and b; Srisang *et al.*, 2021). Further research is needed to confirm their efficacy. These coatings may offer a promising alternative for prevention in the future.

Our study has several limitations that we acknowledge in maintaining transparency and honesty. The small sample size may have affected the power and reliability of the study results. Increasing the sample size could potentially reveal more significant findings. Second, there were fewer male dogs than female dogs in the study. Additionally, differences in the types of urinary catheters used for male and female dogs may have limited the ability to perform comparisons

between these groups. Finally, the study did not have specific criteria for antibiotic use, as all dogs received antibiotics for their underlying conditions. The lack of standardized antibiotic criteria could have influenced the urine culture results. However, our results demonstrated a trend toward higher risk associated with pretreated antimicrobials that created unexpected MDRO in catheterized dogs.

Conclusion

A routine urinalysis is unreliable for predicting CAUTIs in dogs hospitalized in the critical care unit. In this study, dogs that received prior antibiotic treatment exhibited longer CAUTI-free periods following catheter placement than those reported in previous studies. However, a worrying finding emerged from the drug sensitivity tests, which revealed a high prevalence of pathogens with MDR. The acquisition of MDRO created using pretreated antimicrobials without confirmed bacterial culture highlights a growing issue of antibiotic resistance in veterinary medicine, which could complicate treatment and management strategies. Given these concerns, reconsidering prophylactic antibiotics may be advisable, even for dogs at high risk of developing CAUTIs, such as older dogs undergoing short-term urinary catheterization. Implementing serial bacterial culture, drug sensitivity tests, and urine sediment examination using modified Wright's staining could become the new standard routine. The aim of this study was to prevent and delay the risk of further antibiotic resistance in CAUTIs. Future research should focus on validating this approach and exploring additional strategies to mitigate antibiotic resistance in veterinary practice.

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Conflicts of interest

The authors declare no conflicts of interest.

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Author contributions

Conceptualization, G.K.; methodology, P.A. and S.K.; software, P.A. and S.K.; validation, S.K. and G.K.; formal analysis, P.A., S.K., and G.K.; investigation, P.A.; clinical case handling, N.P., N.E., and P.A.; resources, O.D.; data curation, S.K.; writing—original draft preparation, P.A. and G.K.; writing—review and editing, G.K.; visualization, S.K. and O.D.; supervision, G.K.; project administration, S.K. All authors have read and agreed to the publication of the finale version of the manuscript.

Data availability

The data used to support the findings of this study are presented in the supplementary files.

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Table S1. Signalment and history.

Number	Age (year)	Sex	Status	BW (kg)	Breed	Disease	Antibiotics
1	5	F	N	9	french bulldog	Closed pyometra, vector-borne diseases	AMC, doxycycline
2	6	F	I	8.1	french bulldog	Post-operative, pneumonia	Imipenem, metronidazole
3	9	F	I	22.9	thai bangkaew	Post-operative	AMC
4	8	F	N	6.6	crossbreed	Post-operative, pneumonia, pancreatitis	AMC, metronidazole
5	9	F	N	17.8	thai bangkaew	Vector-borne diseases, encephalitis	Doxycycline, marbofloxacin
6	9	F	N	12.2	crossbreed	Hepatic mass, acute kidney injury	AMC
7	3	F	N	5.2	poodle	Canine distemper virus infection	AMC, doxycycline
8	7	F	N	23.1	crossbreed	Diabetes mellitus, pancreatitis	AMC, metronidazole
9	4	F	I	13	welsh corgi	Post-operative	AMC, metronidazole
10	11	F	N	13	welsh corgi	Closed pyometra	AMC
11	15	F	N	36.3	crossbreed	Post-operative	Imipenem, sulfa-trimetroprim
12	12	F	N	4.15	crossbreed	Post-operative	AMC
13	9	F	N	4.1	chihuahua	Post-operative	AMC
14	14	F	N	24.5	golden retriever	Post-operative	AMC
15	8	F	N	15.35	crossbreed	Post-operative	AMC, azithromycin
16	10	F	N	17.8	thai bangkaew	Post-operative	Imipenem, metronidazole
17	11	F	N	4	pomeranian	Post-operative	AMC, azithromycin
18	13	F	N	7.7	shih tzu	Lymphoma, pneumonia	Imipenem, azithromycin
19	12	F	I	5.5	shih tzu	Pancreatitis, cholangiohepatitis, acute kidney injury	Imipenem, doxycycline
20	10	F	N	23.2	siberian husky	Hemorrhagic gastroenteritis	Imipenem, metronidazole, tylosin
21	17	F	N	4.7	poodle	Pancreatitis	Imipenem, metronidazole
22	2	F	N	10.45	french bulldog	Encephalitis	Imipenem, doxycycline
23	8	F	I	25	siberian husky	Pancreatitis, cholangiohepatitis	metronidazole, enrofloxacin
24	10	F	I	10.7	crossbreed	Diabetes mellitus, pancreatitis	Imipenem
25	9	F	N	3.25	pomeranian	Post-operative	AMC
26	13	M	I	20	crossbreed	Pancreatitis, acute kidney injury	Imipenem, metronidazole
27	1	M	I	11.9	crossbreed	Vector-borne diseases	doxycycline, clindamycin
28	7	M	N	12.6	french bulldog	Post-operative	AMC