

Subclinical bacteriuria and pyuria in companion animals without signs of lower urinary tract disease: prevalence and associations in a prospective cross-sectional study using multimodal analytics

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Abstract

Background: Subclinical bacteriuria (SB) and pyuria (SP) are recognized in companion animals, yet their prevalence and comorbidities in those without signs of lower urinary tract disease (LUTD) remain underexplored.

Hypothesis/Objectives: Determine SB and SP prevalence, identify associations, and compare species differences.

Animals: Two hundred eighty-seven cats and 533 dogs without LUTD signs.

Methods: Prospective cross-sectional study with retrospective analysis of medical records.

Results: Subclinical bacteriuria prevalence was 6.67% in cats and 9.81% in dogs. Subclinical pyuria was rarer in cats (1.05%) than in dogs (2.88%). Concurrent SB and SP occurred in 0.3% of cats and 2.5% of dogs ($P = .0275$), highlighting species-specific patterns. Higher urinary white blood cell levels were associated with higher urine bacterial levels ($P < .001$). In cats, key multivariable logistic regression associations increasing the composite outcome variable (SP, SB, or SP and SB) odds included previous diagnoses of lower urinary tract infection (LUTI; odds ratio [OR] 5.6 [95% confidence limit or 95CL 2-15.6]), diabetes mellitus (OR 6.5 [95CL 1.4-30.3]), hyperthyroidism (OR 9.6 [95CL 1.2-77]), and current diagnosis of acute kidney injury (AKI; OR 7.5 [95CL 2.1-27]); in dogs, a previous diagnosis of AKI (OR 9.9 [95CL 1.3-76.9]), and current diagnoses of AKI (OR 9.9 [95CL 2.3-43.5]) and LUTI (OR 23.3 [95CL 12.5-43.5]). Machine learning revealed additional associations, including hypercortisolism in dogs.

Conclusions and clinical importance: These findings underscore distinct risk profiles between species, suggesting tailored diagnostic approaches in veterinary practice. The rarity of concurrent SB and SP, unlike in humans, questions the application of human guidelines to animals.

Keywords comorbidity, companion animals, lower urinary tract disorders, machine learning, veterinary diagnostics

Abbreviations AIC, Akaike information criterion; AKI, acute kidney injury; ASB, asymptomatic bacteriuria; ASP, asymptomatic pyuria; AUC, area under the curve; BPH, benign prostatic hyperplasia; CL, confidence limit; DM, diabetes mellitus; HPF, high-powered field; IDSAG, Infectious Diseases Society of America Guidelines; ISCAID, International Society for Companion Animal Infectious Diseases; LUT, lower urinary tract; LUTD, lower urinary tract disease; LUTI, lower urinary tract infection; OOB, out-of-bag; PC, principal component; PCA, principal component analysis; PLS, partial least squares; Pu/Pd, polyuria/polydipsia; RBC, red blood cell; RF, random forest; SB, subclinical bacteriuria; SP, subclinical pyuria; UPC, urine protein to creatinine ratio; UTI, urinary tract infection; WBC, white blood cell; WGCNA, weighted correlation network analysis

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Introduction

Asymptomatic bacteriuria (ASB), defined as the presence of bacteria in urine without clinical signs of urinary tract infection, is an increasingly recognized phenomenon in human medicine.¹ Pyuria commonly accompanies ASB in human medicine; however, pyuria alone, in the absence of signs of lower urinary tract (LUT) disease or bacteriuria, is not an indication for antimicrobial treatment, consistent with Infectious Diseases Society of America Guidelines (IDSAG).¹ In this manuscript, “asymptomatic pyuria” (ASP) refers to an elevated urinary white blood cell (WBC) count in people without urinary tract symptoms and without bacteriuria. Asymptomatic bacteriuria presents diagnostic and management challenges due to their potential to be mistaken for active infections, which can lead to unnecessary antibiotic use and contribute to antimicrobial resistance.¹ In humans, ASB is prevalent across diverse populations, including healthy women (3%-10%), the elderly (up to 50%), and pregnant women (1.9%-9.5%), with treatment recommended only in specific cases, such as pregnancy or before urologic procedures, to prevent complications like pyelonephritis, as outlined by the IDSAG.² Published reports indicate that subclinical bacteriuria (SB) is observed in 2.1%-12% of dogs and 1%-13% of cats, with estimates varying by population and methodology.³ Similar to IDSAG, the International Society for Companion Animal Infectious Diseases (ISCAID) advises against routine treatment in cases of SB to mitigate resistance risks, emphasizing a conservative approach unless specific clinical indications arise.⁴ Furthermore, in 2019, ISCAID revised its guidelines, advising against routine treatment when SB is accompanied by pyuria (ie, subclinical pyuria [SP] as clinical signs are absent) due to lack of evidence in veterinary medicine that would indicate a different approach to that taken in humans.³

The complexity in making the diagnosis of SB and SP arises from the difficulty in distinguishing harmless bacterial colonization from pathogenic infection, a challenge exacerbated by species-specific differences in urine composition, normal flora, and pathogen profiles. In dogs and cats, common pathogens such as *Escherichia coli* and other Gram-negative bacteria are present in cases of lower urinary tract infection (LUTI) and SB.⁵⁻⁸ In addition to LUTI, SP can stem from noninfectious causes like feline idiopathic cystitis or urolithiasis, necessitating meticulous interpretation of urinalysis results.⁹⁻¹¹ The ability to detect SB is influenced by urine collection methods, cystocentesis versus catheterization versus voided samples, which vary in contamination risk and result reliability.¹²⁻¹⁴ Successfully correlating clinical exam findings, urinalysis indices, hematological markers, and historical and current clinical diagnoses with SB and SP can provide a helpful means of identifying important associations with SB and SP.

Despite growing recognition of SB and SP in companion animals, research is limited, partly because these conditions lack clinical signs. Our aim is to use clinical and historical variables to estimate the pretest probability of SB, SP, or SB and SP in asymptomatic dogs and cats, which in turn will inform selective urine culture, support antimicrobial stewardship, and generate etiologic hypotheses about host and comorbidity factors. Previous studies are largely retrospective and enriched for symptomatic dogs and cats, introducing spectrum and selection biases that limit the generalizability of prevalence and predictor estimates; a prospective, prespecified asymptomatic study group mitigates these biases. Supervised (logistic regression, partial least squares [PLS], and

random forest [RF]) and unsupervised (principal component analysis [PCA], weighted correlation network analysis [WGCNA]) methods are used as exploratory tools to capture linear and nonlinear associations and to summarize patterns of co-variation in high-dimensional data. Applying these tools is particularly valuable in tertiary veterinary settings, where diverse animal populations provide a robust platform for evaluating candidate determinants and correlates of SB, SP, or SB and SP in animals without primary urinary tract complaints.

This study addresses these knowledge gaps by prospectively logging clinical, urinalysis, and demographic data from a study group of dogs and cats evaluated at a University Veterinary Teaching Hospital, for which clients reported no primary complaints related to lower urinary tract disease (LUTD) in that single visit. We then retrospectively analyzed their medical records to identify factors associated with SB and SP. We hypothesized that specific clinical and demographic factors are associated with SB and SP in dogs and cats lacking clinical signs of LUTD, and that the nature of these associations differs significantly between the 2 species. The primary aim was to identify etiologic risk factors for SB and SP. Specifically, our objectives were: (1) determine the prevalence of SB and SP in this subclinical study group, (2) identify key biological risk factors associated with SB and SP, and (3) compare these associated factors between dogs and cats to elucidate species-specific differences. This work addresses a gap previously identified by the ISCAID regarding the lack of veterinary evidence to support a species-specific approach to SB and SP different from that used in human medicine.

Materials and methods

A prospective study group of 287 cats and 533 dogs was identified from December 9, 2019 to September 16, 2021, as presenting without signs of LUTD during clinical visits to the Small Animal Internal Medicine Service at the University of Illinois, Veterinary Teaching Hospital. Animals were prospectively included, and their medical record numbers were logged on an online document if the primary complaint from that single visit was not related to LUTD and if they had a urinalysis performed at that visit (Figure S1). Dogs and cats were excluded from the study group if, during the appointment, the owners reported stranguria, dysuria, gross hematuria, pollakiuria, or perceived urgency. After recruitment concluded, we retrospectively extracted the demographic details, previous and current medical diagnoses, results of physical exam, CBC, serum biochemistry, and routine urinalysis. Routine urinalysis included microscopic examination of unstained wet-mounted urine sediment by a dedicated team of clinical pathology technologists under the supervision of board-certified pathologists, ensuring consistency across all samples. Diagnostic results were limited to the inclusion visit at which the animal was identified for the study. Animals were classified as having SP if there were > 5 WBC per high-powered field (HPF) on the urinalysis urine sediment examination, and as having SB if any bacteria were present. In total, 20/533 dogs (3.8%) and 5/287 cats (1.7%) ultimately received a diagnosis of LUTI or had pollakiuria listed as the primary diagnosis. These cases were retained in the study because the initial owner complaints and clinical context centered on unrelated systemic conditions (eg, diabetes mellitus [DM], hypercortisolism) or generalized signs such as polyuria (Pu) and polydipsia (Pd) and did

not include LUT signs. In all of these cases, the identification of pollakiuria or the decision to diagnose LUTI occurred after the visit and clinician's review of urinalysis or culture results, independent of any clinical signs at presentation (eg, a dog with hypercortisolism or DM with bacteria in the urine). According to the ISCAID guidelines, none of these animals would meet the diagnostic criteria for LUTI, and they were therefore analyzed as subclinical cases in this study.⁴ Nevertheless, we decided to retain the attending clinician-recorded "current diagnosis of LUTI" as a variable. Doing so allowed us to capture the clinician's real-time diagnostic impression and evaluate whether this subjective label, despite guideline discordance, was independently associated with SP, SB, or SP and SB in our models.

Semiquantitative (rare/few/moderate/etc), nominal (eg, bacteria type), or binary (yes/no) outcome variables extracted from the medical records were transformed into numerical ordinal, nominal, or binary categorical variables and recorded on a master spreadsheet.

Statistical analyses were conducted with SAS Studio 3.81 (SAS Institute Inc., Cary, NC, USA). Descriptive statistics, including means, SDs, medians, minima, maxima, and frequency distributions were computed for demographic variables and urinalysis parameters using the MEANS and FREQ procedures. Normal distribution of continuous variables was evaluated by a combination of the Shapiro–Wilk test, histogram, and qq plots. Analysis of variance of normal/log-normal distributed variables between species was performed with the GLM procedure with a linear model that included species as a fixed effect. The chi-square with the Fisher's exact test was used to assess species differences in categorical variables. Binomial variables were analyzed with the FREQ procedure to estimate the prevalence of SB and SP in cats and dogs and their 95% CIs. Among animals with pyuria, we used 1-sample binomial tests with the FREQ procedure to estimate the prevalence of bacteriuria (and its 95% CIs via exact and approximate methods) and to test whether it differed from 50%. Because SB and SP share pathophysiologic drivers, have identical management under ISCAID guidelines, and occur too infrequently to support adequately powered separate models (events-per-variable < 10), we analyzed a composite end-point (SP, SB, or SP and SB) to obtain stable, clinically meaningful estimates without inflating type-I or type-II error. Univariate logistic regression screened independent variables against the composite outcome of SP, SB, or SP and SB. Variables with *P*-values < .2 were retained for multiple logistic regression, which was refined using backward selection with the LOGISTIC procedure. Ordinal logistic regression with a cumulative cloglog link function analyzed the association between the magnitude of SP and SB and included species and collection methods as fixed effects.

Exploratory methods, RF (variable importance), PLS (covariate relationships), PCA with discriminant analysis and hierarchical clustering, and WGCNA (network modules), were applied separately in dogs and cats to identify nonlinear and high-dimensional associations with SP, SB, or SP and SB (see Supporting Information; [Supplementary Table S7](#)).

Results

A total of 820 animals were included in the study, comprising 287 cats and 533 dogs, prospectively collected over 647 days. The mean age (\pm SD) was 10 (\pm 5) years for cats and 8 (\pm 4) years

for dogs. Among cats, 153 were male and 134 were female, with the majority being neutered (98.95%). For dogs, 244 were male and 289 were female, and most were neutered (86.68%). The most common breeds were Domestic Shorthair for cats ($n = 199$, 69.34%) and mixed-breed for dogs ($n = 118$, 22.14%), followed by Labrador Retriever ($n = 35$, 6.57%) and Yorkshire Terrier ($n = 33$, 6.19%). Complete demographic information for dogs and cats is presented in [Table 1](#) and [Table S1](#).

Urinalysis findings and prevalence of SP and SB (Tables 2 and 3)

Urinalysis findings revealed species-specific differences in urine pH, proteinuria, and glucosuria. Dogs had significantly higher urine pH and protein ordinal score than cats, while glucosuria was more common in cats. No significant species differences were observed in urinary WBCs or bacterial ordinal scores. Most samples were collected via cystocentesis, with free catch used more frequently in dogs. The prevalence of SP and SB was low in both species and did not differ significantly between species ($P = .0927$ and $P = .1304$, respectively; [Table 3](#)). However, among animals with SP, dogs were significantly more likely than cats to also have SB. Among SP cats ($n = 3$), SB was present in (1/3) and absent in (2/3). Among SP dogs ($n = 15$), the prevalence of SB was significantly higher at 86.67% (13/15) than subclinically pyuric non-bacteriuric dogs (13.3% [2/15]; $P = .005$).

Ordinal logistic regression analysis for pyuria magnitude predicting bacteriuria ($n = 802$; dogs and cats combined) (Table 4)

Model fit improved with the inclusion of covariates ($-2 \text{ Log L: } 608.58\text{--}526.655$; Akaike information criterion [AIC]: 614.580–542.655), and the association between predicted probabilities and observed responses was moderate (Somers' $D = 0.407$, $c = 0.704$), suggesting decent predictive performance. The ordinal regression analysis demonstrated a robust positive association between increasing urinary WBC ordinal levels and higher ordinal levels of bacteria in the urine. Higher urine WBC levels were strongly associated with higher odds of higher urine bacterial scores. Compared to animals with WBC level 0, those with WBC levels of 5, 10, and 20 had approximately 10-, 100-, and 240-fold greater odds, respectively, of being in a higher bacterial category. All associations were statistically significant. Neither species ($P = .147$) nor collection method ($P = .272$) contributed significantly to the model once the WBC ordinal category was included. These findings underscore the magnitude of pyuria as the predominant factor predicting more severe bacteriuria in subclinical dogs and cats, with species- and collection-related variables displaying minimal impact.

Logistic regression analysis for associations with SP, SB, or SP and SB (Tables 5 and 6)

Univariate logistic regression for cats identified previous diagnoses of LUTI ($P < .001$), acute kidney injury (AKI) ($P = .005$), hyperthyroidism ($P = .130$), and DM ($P = .186$), current diagnosis of AKI ($P = .005$) and diet ($P = .042$) as associated with SP, SB, or SP

Table 1 Demographic information for cats and dogs without signs of lower urinary tract disease.

	Cats (<i>n</i> = 287)	Dogs (<i>n</i> = 533)
Age (mean ± SD)^a	10 ± 5	8 ± 4
Body weight (mean ± SD)^b	4 ± 1	17 ± 13
Sex	Male—153 (53.3%) Female—134 (46.7%)	Male—244 (45.8%) Female—289 (54.2%)
Neuter status	1 (0.35%) intact—Male 152 (53%) neutered—Male 2 (0.7%) intact—Female 132 (46%) neutered—Female	40 (7.5%) intact—Male 204 (38.3%) neutered—Male 31 (5.8%) intact—Female 258 (48.4%) neutered—Female

^aAge is reported in years. ^bBody weight is reported in kg.

Table 2 Urinalysis findings in cats and dogs without signs of lower urinary tract disease.

Variable	Cats	Dogs	Statistic; <i>P</i> value
Urine pH	Mean = 6.5 (SD = 0.6), <i>n</i> = 287	Mean = 7.1 (SD = 1.0), <i>n</i> = 533	<i>F</i> = 76.99; <i>P</i> < .001
Proteinuria (ordinal score)	Mean = 1.1 (SD = 0.8, median = 1, range = 0-3), <i>n</i> = 287, 0+ (20%), 1+ (50.1%), 2+ (24.2%), 3+ (4.9%)	Mean = 1.3 (SD = 1.0, median = 1, range = 0-3), <i>n</i> = 533, 0+ (26.3%), 1+ (35%), 2+ (22.2%), 3+ (16.4%)	$\chi^2 = 34.507$; <i>P</i> < .001
Glucosuria (ordinal score)	Mean = 0.4 (SD = 0.8, median = 0, range = 0-3), <i>n</i> = 287, 0+ (82.1%), 1+ (8.1%), 2+ (2.5%), 3+ (7.4%)	Mean = 0.2 (SD = 0.6, median = 0, range = 0-3), <i>n</i> = 533, 0+ (90%), 1+ (5.8%), 2+ (0.8%), 3+ (3.7%)	$\chi^2 = 11.479$; <i>P</i> = .009
WBC (Ordinal)	Mean = 3.7 (SD = 2.8, median = 5, range = 0-20), <i>n</i> = 287, 0 (28.4%), 5 (70.6%), 10 (0%), 20 (1.1%)	Mean = 4.1 (SD = 3.1, median = 5, range = 0-20), <i>n</i> = 533, 0 (24.7%), 5 (72.7%), 10 (0.8%), 20 (1.9%)	Fisher's exact <i>P</i> = .283
Urine bacteria (Ordinal)	Mean = 0.1 (SD = 0.5, median = 0, range = 0-3), <i>n</i> = 287, 0+ (93.3%), 1+ (4.6%), 2+ (0.3%), 3+ (1.7%)	Mean = 0.2 (SD = 0.6, median = 0, range = 0-3), <i>n</i> = 533, 0+ (90.2%), 1+ (5.4%), 2+ (1.9%), 3+ (2.5%)	Fisher's exact <i>P</i> = .252
Collection method	Cystocentesis: 99.65%, free catch: 0.35%, <i>n</i> = 284	Cystocentesis: 91.51%, free catch: 8.49%, <i>n</i> = 518	Fisher's exact <i>P</i> < .001

Abbreviation: WBC = white blood cell.

Table 3 Prevalence of SP and SB in cats and dogs without signs of lower urinary tract disease.

Category	Cats	Dogs	Statistic; <i>P</i> value
SP (WBC > 5)	1.05% (3/285); 95% CI, 0.22%-3.05%	2.88% (15/520); 95% CI, 1.62%-4.71%	$\chi^2 = 2.83$, <i>P</i> = .093
SB	6.67% (19/285); 95% CI, 4.06%-10.22%	9.81% (51/520); 95% CI, 7.39%-12.69%	$\chi^2 = 2.29$, <i>P</i> = .130
SP with SB	33.33% (1/3); 95% CI 0.84%-90.57%	86.67% (13/15); 95% CI, 59.54%-98.34%	$\chi^2 = 4.86$, <i>P</i> = .028; <i>Z</i> = -2.84, <i>P</i> = .005 ^a

^aRefers to a significant difference between bacteriuric dogs with and without pyuria. Abbreviations: 95% CI = Exact (Clopper–Pearson) 95% CI; WBC = white blood cell.

Table 4 Ordinal logistic regression of bacteriuria severity: adjusted odds ratios (ORs) (95% CI) for WBC categories.

WBC level	Estimate	SE	Wald χ^2	OR	95% CI	<i>P</i> -value
0	Reference level					
5	2.331	0.719	10.497	10.29	2.51-42.13	.001
10	4.629	0.936	24.452	102.44	16.35-641.75	<.001
20	5.498	0.774	50.469	244.11	53.56-1112.51	<.001

White blood cell (WBC) level 0: no WBC per high power field (HPF); WBC level 5: up to 5 WBC per HPF; WBC level 10: up to 10 WBC per HPF; WBC level 20: up to 20 WBC per HPF.

and SB to be included in the multivariable regression model. The diet was excluded from the final multivariable regression model because of a high number of missing data (*n* = 109). Univariate logistic regression for dogs identified a previous diagnoses of LUTI (*P* = .007) and AKI (*P* = .118), current diagnoses of LUTI

(*P* < .001), benign prostatic hyperplasia (BPH) (*P* = .042), urinary stones (*P* = .196), polypoid cystitis (*P* = .118), AKI (*P* = .026), hypercortisolism (*P* = .113), and Lyme disease (*P* = .083) as associated with SP, SB, or SP and SB to be included in the multivariable regression model. Diagnosis of Lyme disease and diagnosis of

Table 5 Multivariable logistic regression predicting SP, SB, or SP and SB in cats: adjusted odds ratios (95% CI).

Condition	Estimate	SE	Wald χ^2	OR	95% CI	P-value
Previous diagnosis of LUTI	-1.727	0.518	11.112	5.62	2.04-15.63	.001
Previous diagnosis of DM	-1.880	0.782	5.783	6.54	1.41-30.3	.016
Previous diagnosis of hyperthyroidism	-2.261	1.050	4.637	9.62	1.22-76.92	.031
Current diagnosis of AKI	-2.009	0.655	9.417	7.46	2.08-27.03	.002

Abbreviations: AKI = acute kidney injury; DM = diabetes mellitus; LUTI = lower urinary tract infection; OR = odds ratio; SB = subclinical bacteriuria; SP = subclinical pyuria.

Table 6 Multivariable logistic regression predicting SP, SB, or SP and SB in dogs: adjusted odds ratios (95% CI).

Condition	Estimate	SE	Wald χ^2	OR	95% CI	P-value
Previous diagnosis of AKI	-2.295	1.034	4.922	9.90	1.30-76.92	.027
Current diagnosis of LUTI	-3.137	0.327	92.307	23.26	12.50-43.48	<.001
Current diagnosis of AKI	-2.295	0.742	9.580	9.90	2.33-43.48	.002

Abbreviations: AKI = acute kidney injury; LUTI = lower urinary tract infection; OR = odds ratio; SB = subclinical bacteriuria; SP = subclinical pyuria.

BPH were excluded from the final multivariable regression model because of a high number of missing data ($n = 469$ and $n = 334$, respectively). Separate logistic regression models using a binary cloglog link function were constructed for cats and dogs due to species-specific differences.

Two hundred eighty-seven cats were included in the multivariable logistic regression (2 observations were excluded due to missing data in either explanatory or response variables). Compared to an intercept only model, the full model fit statistics improved ($-2 \text{ Log L: } 144.833\text{-}122.616$; AIC: $146.833\text{-}132.616$), with significant likelihood ratio ($\chi^2 = 22.216$, $P = .001$), score ($\chi^2 = 35.5656$, $P < .001$), and Wald tests ($\chi^2 = 34.1512$, $P < .001$). The model's area under the curve (AUC) was 0.665. The final model after backward elimination included previous diagnoses of LUTI, DM, and hyperthyroidism, and current diagnosis of AKI as significantly associated with SB or SP, or both, ($P < .05$). Previous diagnoses of LUTI, DM, or hyperthyroidism, or current diagnosis of AKI increased the SP, SB, or SP and SB odds by approximately 5.6-9.6 times.

A total of 533 dogs were included in the multivariable logistic regression (3 observations were excluded due to missing data in either explanatory or response variables). Compared to an intercept only model, the full model-fit statistics improved ($-2 \text{ Log L: } 344.588\text{-}277.329$; AIC: $346.588\text{-}285.329$), with significant likelihood ratio ($\chi^2 = 10.850$, $P = .004$), score ($\chi^2 = 13.485$, $P = .001$), and Wald tests ($\chi^2 = 67.259$, $P < .001$). The model's AUC was 0.673. The final model included a previous diagnosis of AKI and current diagnoses of AKI and LUTI as significant associations ($P < .05$). A previous diagnosis of AKI or current diagnoses of LUTI or AKI increased the SP, SB, or SP and SB odds by approximately 9.9-23.25 times.

Random forest analysis (Tables S2 and S6)

In dogs, the model demonstrated robust predictive performance, achieving an out-of-bag (OOB) misclassification rate of approximately 10%, indicating correct classification of 90% of unseen data. Constructed with 100 trees and evaluating 11 variables per split, the model identified current diagnosis of LUTI as the most influential association. Other notable contributors included urine red blood cell (RBC) and serum cholesterol concentration.

In cats, the model, constructed with 100 trees and an inbag fraction of 0.6, exhibited robust predictive performance, achieving an OOB misclassification rate of approximately 7.3%, corresponding to a 92.7% correct classification rate for unseen data. Among the most influential associations were current diagnosis of AKI and a previous diagnosis of LUTI. Conversely, variables such as pollakiuria and reproductive status showed no associative value, with zero importance across all metrics.

Partial least squares regression (Tables S3 and S6)

In dogs, PLS analysis extracted 15 factors from 105 variables to explain 55.47% of the variance in the composite dependent variable SP, SB, or SP and SB, and 34.98% of the variance in the variables, based on 426 observations from an initial 533. The first factor alone accounted for 35.93% of the dependent variable's variance, with subsequent factors contributing progressively less. Key positive associations included current diagnoses of LUTI (variable estimate: 0.433), hypercortisolism (0.174), and peripheral blood count of monocytes (0.191), while immunosuppression from disease (-0.181), measuring urine protein to creatinine ratio (UPC) (-0.154), and serum albumin concentration (-0.141) showed negative associations.

In cats, although the initial PLS analysis nominally extracted up to 15 factors explaining up to 47.12% of variance, internal validation (leave-one-out cross-validation) indicated that no predictive latent factors improved model prediction beyond chance. Thus, PLS did not provide reliable insight into the structure of factors associated with the composite outcome in the feline study group, likely due to low event counts and substantial heterogeneity.

PCA-based hierarchical clustering correlation analysis (Tables S4 and S6)

In dogs, the dimensionality of the clinical and laboratory dataset was reduced to 34 principal components (PCs), accounting for

70% of the total variation in the dataset. Canonical discriminant analysis indicated that the outcome variable explains 37.6% of the variation in the canonical variable and that PC8 and PC20 were key discriminators within the canonical variable. The key raw positive and negative loadings in PC8 included clinical hematuria, and ordinal levels of blood and RBCs on urinalysis (positive), and administration of angiotensin receptor blockers, UPC and segmented WBCs on CBC (negative); key raw positive and negative loadings in PC20 included a previous diagnosis of spinal cord disease, and current diagnosis of bladder and urethral tumors (positive), and body condition score, and previous diagnoses of leptospirosis and Lyme disease (negative). The loadings from the PCA were clustered using Ward's method to group-related features within 17 distinct clusters, and Pearson correlation coefficients were calculated between individual features and the composite outcome SP, SB, or SP and SB to elucidate their direct associations. Clusters 2, 6, 9, and 16 were strongly associated with a positive outcome, and clusters 3 and 14 were strongly associated with a negative outcome. Clusters 2, 6, 9, and 16 features included peripheral blood counts of neutrophils and monocytes, current diagnoses of LUT tumors and LUTI, microscopic presence of blood in the urine, sex, and a previous diagnosis of AKI. Clusters 3 and 14 features included peripheral blood counts of eosinophils, basophils, and peripheral blood hemoglobin concentration and hematocrit.

In cats, the dimensionality of the clinical and laboratory dataset was reduced to 25 PCs, accounting for 68.4% of the total variation in the dataset. Canonical discriminant analysis indicated that the outcome variable explains 22.45% of the variation in the canonical variable and that PC1 and PC4 were key discriminators within the canonical variable. The key raw positive and negative loadings in PC1 included serum glucose concentration and anion-gap, and urinary glucose ordinal levels (positive), and serum sodium and chloride concentrations (negative); key raw positive and negative loadings in PC4 included serum creatinine concentration and a current diagnosis of AKI (positive), and current diagnosis of DM and immunosuppression from disease (negative). Clusters 2, 3, 4, and 7 were strongly biased toward a positive outcome, and cluster 12 was strongly biased toward a negative outcome. Clusters 2, 3, 4, and 7 features included age, Pu/Pd, and current diagnoses of hyperthyroidism and upper/lower UTI, urinary mucus and casts, peripheral blood hemoglobin concentration, Hct and RBC concentration, and microscopic presence of blood on urinalysis. Cluster 12 features included the peripheral blood count variables mean corpuscular volume and mean corpuscular hemoglobin.

Weighted correlation network analysis (Tables S5 and S6)

In a WGCNA conducted separately for dogs and cats, 2 out of 8 and 1 out of 5 distinct clusters of variables in dogs and cats, respectively, were identified as significantly associated with the composite outcome variable SP, SB, or SP and SB, revealing species-specific patterns. For dogs, cluster 3, which included urinary cast ordinal levels and type of urinary cast, showed a weak positive correlation ($r = 0.101, P = .004$), indicating that the presence or type of urinary casts is associated with SP, SB, or SP and SB. Similarly, cluster 4 in dogs, comprising a wide range of clinical variables including, age, hematological and biochemical variables, clinical signs, current diagnoses, and urinalysis findings, demonstrated

a significant weak positive association ($r = 0.110, P = .005$). For cats, cluster 2, encompassing a wide range of variables, including clinical signs, CBC and urinalysis variables, and past and present diagnoses, exhibited a positive correlation ($r = 0.105, P = .007$). In both species, the remaining clusters did not have significant correlations with the composite outcome variable ($P > .05$).

Discussion

This study prospectively identified 287 cats and 533 dogs presenting for clinical evaluation for reasons other than current signs of LUTD over a 21-month period, subsequently analyzing their medical records to characterize the prevalence, co-occurrence, and associations with SP, SB, or SP and SB. Our findings highlight similarities and differences with existing veterinary and human literature, delineating species-specific patterns in subclinical urinary findings. Given current ISCAID guidance's use of human paradigms when veterinary data are limited, these observations caution against uncritical extrapolation; however, evaluating management strategies was beyond the scope of this study.

The prevalence of SB in our study group was 6.67% in cats and 9.81% in dogs, consistent with estimates of 1%-13% in healthy cats and approximately 2.1%-12% in healthy dogs.³ These prevalences are lower than those in some human study groups, where ASB affects 3%-10% of healthy women and up to 50% of elderly individuals,¹ possibly due to our prospective focus on animals without LUTD concerns, identified during routine visits for unrelated clinical issues. Subclinical pyuria, defined as > 5 white blood cells per HPF, was less prevalent at 1.05% in cats and 2.88% in dogs. The co-occurrence of SP and SB was rare, observed in 0.35% of cats (1/287) and 2.5% of dogs (13/520), suggesting that inflammation infrequently accompanies SB in these species. This contrasts with human studies, where ASP often co-occurs with ASB but does not warrant treatment unless symptomatic.^{1,15,16} Given this disparity, the recent ISCAID guidelines, which advise against treating concurrent SP and SB based on human data, might require reconsideration, as the high co-occurrence in humans does not align with the low prevalences in our study group. A significant species difference emerged in SP with SB (0.3% in cats vs 2.5% in dogs, $P = .028$), indicating that dogs with SP are more likely than cats to have concurrent SB. This might reflect anatomical or immunological factors, such as dogs' greater susceptibility to LUTI.

We found a strong association between the urine ordinal levels of WBC and bacteria ($P < .001$). Higher WBC levels were linked to more bacteria, suggesting a dose-response relationship in which inflammation escalates with bacterial load. This association held across the cohort, unaffected by species ($P = .147$) or collection method ($P = .271$). The authors acknowledge that even though the collection method had a nonsignificant effect, free-catch contamination remains a potential source of misclassification. In human medicine, the diagnostic value of ASP is debatable in determining the clinical significance of bacteriuria because ASP occurs commonly without bacteriuria in noninfectious LUTD.² However, our findings indicate a consistent link between SP and SB in dogs and cats, wherein urine WBC and bacterial ordinal levels increase concomitantly. Our findings highlight apparent differences in the occurrence of SP, SB, or SP and SB between cats, dogs, and humans, suggesting that dogs and cats might not mirror human patterns and therefore should not be managed solely based on human guidelines.³ However, this association

alone oversimplifies treatment decisions, which should also weigh clinical outcomes and risks, areas where veterinary data are lacking and beyond this study's scope. While we explored associations with SP, SB, or SP and SB using multivariable logistic regression and advanced machine-learning methods, longitudinal studies are needed to assess outcomes tied to these associations. Notably, in the ordinal logistic regression, we could not analyze dogs and cats separately due to low SP and SB prevalence in cats and fewer WBC ordinal categories in cats compared to dogs, necessitating a combined dataset (which we acknowledge as a limitation). Even when dogs and cats were combined, the low prevalences of SP and SB skewed the data, inflating estimates and 95% CIs in the cumulative cloglog model.

Multivariable logistic regression identified distinct associations with SP, SB, or SP and SB between species. In cats, a previous diagnosis of LUTI, DM, hyperthyroidism, or a current diagnosis of AKI was associated with 5.6-9.6 times higher SP, SB, or SP and SB odds. In dogs, a previous diagnosis of AKI or current diagnosis of LUTI or AKI was associated with 9.9-23.25 times higher odds. These variables are aligned with veterinary literature linking metabolic and renal stressors to elevated SB risk³ and parallel human data, where comorbidities like DM heighten ASB risk due to impaired immunity.^{1,2} A recent study did not identify hyperthyroidism in cats to be significantly associated with SB.¹⁷ In that study, only cats with overt hyperthyroidism were enrolled, and quantitative cultures and univariable analyses were used. In contrast, our cohort included all cats presenting to the SAIM Service, only a subset of which were hyperthyroid, and we adjusted for age, AKI, and DM in our multivariable model. Thus, differences in inclusion criteria, culture methodology (quantitative vs sediment cytology), and covariate adjustment likely explain the discrepant results. We postulate that chronic hyperthyroidism, especially in older dogs and cats, induces sustained glomerular hyperfiltration and leads to tubular injury, which can impair urinary defenses and promote subclinical bacterial colonization.

The consistent role of AKI in both species suggests renal compromise might predispose animals to SP, SB, or SP and SB. An *in vitro* study in dogs¹⁸ showed that urine concentration and pH significantly affect *E coli* growth, supporting the hypothesis that declining renal function could alter these variables to favor bacterial proliferation. Other mechanisms or combined factors likely contribute, warranting mechanistic studies to clarify how renal impairment drives SP, SB, or SP and SB in these species.

The apparently strong effect of "current diagnosis of LUTI" in dogs likely reflects diagnostic bias rather than an actual infection: clinicians tended to record LUTI whenever bacteriuria ± pyuria appeared in dogs with pre-existing endocrinopathies or renal disease, even though these cases lacked clinical signs and did not satisfy ISCAID criteria. Consequently, the variable acts as a surrogate marker for SP, SB, or SP and SB in a predisposed animal rather than an independent disease state.

Diet in cats and current diagnoses of Lyme disease and BPH in dogs were excluded from the multivariable analysis due to a high number of missing data ($n = 109$, $n = 469$, and $n = 334$, respectively). Diet in cats ($P = .042$) and BPH in dogs ($P = .042$) were significantly associated with SP, SB, or SP and SB in univariate logistic regression, while Lyme disease ($P = .083$) approached significance; their roles merit investigation in studies with more complete data.

Advanced statistical and machine-learning methods revealed additional associations and species-specific patterns of SP, SB,

or SP and SB that complement the logistic regression findings. Principal component analysis loadings and WGCNA "module eigengenes" do not represent causal effects; they summarize patterns of covariation among clinical features. We report these signals only where they corroborate regression findings and note that observed correlations (typically small) are hypothesis-generating and require prospective validation. In dogs, RF analysis highlighted the current diagnosis of LUTI as the top association, while in cats, previous diagnosis of LUTI and current diagnosis of AKI emerged as a strong association. These results underscore the importance of LUT and renal factors, corroborating earlier studies linking prior LUTI to SB in dogs.^{6,19} Partial least squares regression identified current diagnoses of LUTI and hypercortisolism in dogs, aligning with human data showing an elevated risk of ASB in endocrine disorders^{1,2} and with a previous veterinary report implicating chronic kidney disease in SB risk among cats.²⁰ Principal component analysis-based hierarchical clustering reinforced the association of previous LUTI and AKI with SP, SB, or SP and SB in both species, while in dogs, WGCNA additionally tied urinary casts to SP, SB, or SP and SB. These findings suggest that although renal and inflammatory markers consistently influence risk across species, cats might exhibit a broader interplay of clinical factors, possibly reflecting their susceptibility to idiopathic cystitis.²¹ The low prevalence of SP and SB in our study group (1.05%-2.88% and 6.67%-9.81%, respectively) reinforces the need for cautious interpretation of SP and SB, as highlighted by ISCAID guidelines.³ The use of advanced machine-learning methods proved valuable for discovering new variables associated with SP, SB, or SP and SB in dogs and cats, which is critical for the genesis of future hypotheses.

The low prevalence of SP in our study group (1.05% in cats, 2.88% in dogs) contrasts sharply with its frequent co-occurrence with ASB in humans, questioning the relevance of human diagnostic thresholds for veterinary practice. In cats, only 0.3% had concurrent SP and SB, possibly due to their typically concentrated urine, which is considered to have a hindering effect on bacterial growth, whereas in dogs, 2.5% had concurrent SP and SB, suggesting a stronger inflammatory response potentially linked to their reported higher prevalence of LUTI.^{5,7} This species difference highlights the challenge of applying uniform management strategies and supports the need for tailored species-specific approaches.

This study has limitations that should be considered when interpreting its findings. A key limitation is our reliance on semi-quantitative unstained wet-mounted sediment analysis rather than quantitative urine cultures, which remain the gold standard. Although unstained wet-mount sediment cytology offers a rapid, practical screening method via microscopic examination, its lower specificity (approximately 90%) and sensitivity (approximately 80%) compared to cultures might lead to over- or underestimation of SB prevalence due to contamination or low bacterial loads.^{22,23} Our prospective design, which targeted dogs and cats without primary LUTD complaints during routine visits, justified this approach. Given the absence of clinical signs, culturing was not indicated per standard veterinary guidelines,³ aligning with our aim to characterize subclinical findings in a real-world setting. In addition, the retrospective medical record review risked incomplete or inconsistent documentation, potentially affecting modeling accuracy. Despite these constraints, the prospective identification of SB cases enhances the applicability of our

findings to clinical scenarios where SB is initially detected without clinical signs. Lastly, although correlations between individual variables and SP, SB, or SP and SB were weak (eg, $r = 0.1$), their value lies beyond their immediate clinical utility. From a systems biology perspective, these subtle relationships form a network of interactions that might reflect underlying disease mechanisms. While a single variable at this level might not alter a clinician's daily practice, collectively, these findings could point to early disruptions in urinary or immune protective mechanisms. With further validation, such insights might 1 day inform new diagnostic or therapeutic strategies, though we must cautiously interpret these weak correlations until their biological relevance is confirmed.

Conclusions

Our results indicate that SB in dogs and cats is moderately prevalent, with SP being rare yet strongly associated with bacteriuria. Key associations, AKI, endocrinopathies, and previous diagnosis of LUTD, highlight the role of comorbidities, aligning with but expanding on human and veterinary literature. The significant association between urinary ordinal levels of WBC and bacteria suggests a biologically plausible link warranting further study. The rarity of SP concurrent with SB highlights species differences from humans and advocates for a nuanced approach in veterinary medicine.

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Author contributions

Jessica Tallaksen (Data curation, Formal analysis, Project administration, Writing—original draft, Writing—review & editing), Jennifer M. Reinhart (Conceptualization, Methodology, Writing—review & editing), Nicolas Lopez (Formal analysis, Writing—review & editing), and Arnon Gal (Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing—original draft, Writing—review & editing)

Supplementary material

Supplementary material is available at *Journal of Veterinary Internal Medicine* online.

Conflicts of interest

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Off-label antimicrobial use

The authors declare no off-label use of antimicrobials.

Institutional animal care and use committee or other approval declaration

Approval was not required for this study because all animal data analyzed were obtained from retrospective review of existing medical records. No interventions, treatments, or prospective research activities were performed on the animals beyond the collection of data already documented during routine clinical care. Only the animals' medical record numbers were logged prospectively for data collection purposes, and no procedures were conducted that would have required ethical oversight.

Human ethics approval declaration

The authors declare human ethics approval was not needed.

References

1. Nicolle LE, Bradley S, Colgan R, et al. Infectious Diseases Society of America guidelines for the diagnosis and treatment of asymptomatic bacteriuria in adults. *Clin Infect Dis*. 2005;40:643-654. <https://doi.org/10.1086/427507>
2. Nicolle LE, Gupta K, Bradley SF, et al. Clinical practice guideline for the management of asymptomatic bacteriuria: 2019 update by the Infectious Diseases Society of America. *Clin Infect Dis*. 2019;68:1611-1615. <https://doi.org/10.1093/cid/ciz021>
3. Weese JS, Blondeau J, Boothe D, et al. International Society for Companion Animal Infectious Diseases (ISCAID) guidelines for the diagnosis and management of bacterial urinary tract infections in dogs and cats. *Vet J*. 2019;247:8-25. <https://doi.org/10.1016/j.tvjl.2019.02.008>
4. Weese JS, Blondeau JM, Boothe D, et al. Antimicrobial use guidelines for treatment of urinary tract disease in dogs and cats: antimicrobial guidelines working group of the international society for companion animal infectious diseases. *Vet Med Int*. 2011;2011:263768. <https://doi.org/10.4061/2011/263768>
5. Farag HS, Ali ME, Abdel Maseih ES, Bakry NM. Diagnostic ultrasonography and antimicrobial resistance of different pathogens associated with canine and feline lower urinary tract disorders. *Comp Immunol Microbiol Infect Dis*. 2024;112:102216. <https://doi.org/10.1016/j.cimid.2024.102216>
6. LeCuyer TE, Sellon RK, Byrne BA, et al. Multicenter molecular investigation of recurrent *Escherichia coli* bacteriuria in dogs. *Vet Microbiol*. 2024;288:109914. <https://doi.org/10.1016/j.vetmic.2023.109914>
7. Lopez-Cordova J, Machuca P, Araya-Contreras T, et al. Prevalence and antimicrobial susceptibility profile of uropathogens in dogs and cats with signs of urinary tract infection. *J Small Anim Pract*. 2025;66:177-186. <https://doi.org/10.1111/jsap.13800>
8. Teichmann-Knorrn S, Dorsch R. Significant bacteriuria in cats: urinary tract infection and subclinical bacteriuria—a current review. *Tierarztl Prax Ausg K Kleintiere Heimtiere*. 2018;46:247-259. <https://doi.org/10.15654/TPK-180521>

9. Saevik BK, Trangerud C, Ottesen N, Sorum H, Eggertsdottir AV. Causes of lower urinary tract disease in Norwegian cats. *J Feline Med Surg*. 2011;13:410-417. <https://doi.org/10.1016/j.jfms.2010.12.012>
10. He C, Fan K, Hao Z, Tang N, Li G, Wang S. Prevalence, risk factors, pathophysiology, potential biomarkers and management of feline idiopathic cystitis: an update review. *Front Vet Sci*. 2022;9:900847. <https://doi.org/10.3389/fvets.2022.900847>
11. Schechter RD. The significance of bacteria in feline cystitis and urolithiasis. *J Am Vet Med Assoc*. 1970;156:1567-1573. <https://doi.org/10.2460/javma.1970.156.11.1567>
12. Coffey EL, Gomez AM, Ericsson AC, et al. The impact of urine collection method on canine urinary microbiota detection: a cross-sectional study. *BMC Microbiol*. 2023;23:101. <https://doi.org/10.1186/s12866-023-02815-y>
13. Sorensen TM, Jensen AB, Damborg P, Bjornvad CR, Guardabassi L, Jessen LR. Evaluation of different sampling methods and criteria for diagnosing canine urinary tract infection by quantitative bacterial culture. *Vet J*. 2016;216:168-173. <https://doi.org/10.1016/j.tvjl.2016.08.007>
14. van Duijkeren E, van Laar P, Houwers DJ. Cystocentesis is essential for reliable diagnosis of urinary tract infections in cats. *Tijdschr Diergeneeskd*. 2004;129:394-396.
15. Hooton TM, Scholes D, Stapleton AE, et al. A prospective study of asymptomatic bacteriuria in sexually active young women. *N Engl J Med*. 2000;343:992-997. <https://doi.org/10.1056/NEJM200010053431402>
16. Luu T, Albarillo FS. Asymptomatic bacteriuria: prevalence, diagnosis, management, and current antimicrobial stewardship implementations. *Am J Med*. 2022;135:e236-e244. <https://doi.org/10.1016/j.amjmed.2022.03.015>
17. Peterson ME, Li A, Soboroff P, Bilbrough GE, Rishniw M. Hyperthyroidism is not a risk factor for subclinical bacteriuria in cats: a prospective cohort study. *J Vet Intern Med*. 2020;34:1157-1165. <https://doi.org/10.1111/jvim.15769>
18. Thornton LA, Burchell RK, Burton SE, et al. The effect of urine concentration and pH on the growth of *Escherichia coli* in canine urine in vitro. *J Vet Intern Med*. 2018;32:752-756. <https://doi.org/10.1111/jvim.15045>
19. Seguin MA, Vaden SL, Altier C, Stone E, Levine JF. Persistent urinary tract infections and reinfections in 100 dogs (1989-1999). *J Vet Intern Med*. 2003;17:622-631. <https://doi.org/10.1111/j.1939-1676.2003.tb02492.x>
20. Puchot ML, Cook AK, Pohlit C. Subclinical bacteriuria in cats: prevalence, findings on contemporaneous urinalyses and clinical risk factors. *J Feline Med Surg*. 2017;19:1238-1244. <https://doi.org/10.1177/1098612X16688806>
21. Taylor S, Boysen S, Buffington T, et al. iCatCare consensus guidelines on the diagnosis and management of lower urinary tract diseases in cats. *J Feline Med Surg*. 2025;27:1-36. <https://doi.org/1098612X241309176>
22. Lippi I, Habermaass V, Gori E, Ebani VV, Pierini A, Marchetti V. Urinary cytology: potential role in canine urinary tract infections. *Vet Sci*. 2022;9:304. <https://doi.org/10.3390/vetsci9060304>
23. O'Neil E, Horney B, Burton S, Lewis PJ, MacKenzie A, Stryhn H. Comparison of wet-mount, Wright-Giemsa and Gram-stained urine sediment for predicting bacteriuria in dogs and cats. *Can Vet J*. 2013;54:1061-1066.