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Serial point-prevalence surveys to estimate antibiotic use in a small animal veterinary teaching hospital, November 2018 to October 2019

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Abstract

Background: There is no standardized methodology to measure antibiotic drug use (AU) in small animal veterinary hospitals.

Objectives: To estimate AU prevalence in a small animal veterinary teaching hospital and characterize usage by indication and evidence of infection. To establish an AU measurement methodology for veterinary settings.

Animals: Electronic medical records of cats and dogs seen by primary care, urgent care, emergency and critical care, internal medicine, and surgery services during November 2018 to October 2019.

Methods: On 1 day each month, data (signalment, visit reason, diagnostics, and antibiotic details, including indication) were collected for all animals seen on study services.

Results: Of 168 inpatient dogs and 452 outpatient dogs, 98 (58.3%) and 107 (23.7%,) were receiving at least 1 antibiotic on the day of data collection, respectively. For cats 15/49 (30.6%) inpatients and 29/187 (15.5%) outpatients were receiving at least 1 antibiotic. Common drug classes prescribed for dogs were potentiated penicillins (28.7%), first-generation cephalosporins (22.1%), and nitroimidazoles (14.7%), and for cats, common drug classes administered were potentiated penicillins (26.9%), fluoroquinolones (13.5%), and penicillins (11.5%). Common indications for antibiotics included skin, respiratory, gastrointestinal, perioperative, aural, and urinary conditions.

Conclusions and Clinical Importance: Serial point-prevalence surveys (PPS) can estimate AU in a large specialty hospital setting and identify targets for antimicrobial stewardship. The methodology developed during this study can be adapted for use in private practice, including large animal practice. Mirroring methods used in human

Abbreviations: AMR, antimicrobial resistance; AS, antimicrobial stewardship; AU, antibiotic drug use; AVMA, American Veterinary Medical Association; C&S, culture and susceptibility; CDC, Centers for Disease Control and Prevention; CI, confidence interval; EMR, electronic medical record; FDA, Food and Drug Administration; ISCAID, International Society for Companion Animal Infectious Diseases; PPS, point-prevalence survey; UMN, University of Minnesota; VMC, Veterinary Medical Center.

healthcare, the data collection tool can also be used to describe AU nationally through completion of national PPS.

KEYWORDS
antibiotic indication, antibiotic measurement, antimicrobial resistance, antimicrobial stewardship, public health

1 | INTRODUCTION

Antimicrobial stewardship (AS) is essential to local, national, and global initiatives to combat antimicrobial resistance (AMR). The American Veterinary Medical Association (AVMA) has described AS in the veterinary profession as "the actions veterinarians take individually and as a profession to preserve the effectiveness and availability of antimicrobial drugs through conscientious oversight and responsible medical decision-making while safeguarding animal, public, and environmental health."[1] The American Veterinary Medical Association (AVMA) has identified 5 core principles of AS, notably including commitment to stewardship, selection and use of antimicrobial drugs judiciously, and evaluation of antimicrobial drug use practices.[1] Measurement of antibiotic drug use (AU) is an essential step in improving prescribing practices. Antibiotic drug use data are used to describe baseline practices, identify opportunities for improvement, guide goal setting, and measure progress. Centers for Disease Control and Prevention (CDC) uses the point-prevalence survey (PPS) methodology to estimate national rates of AU and healthcare-associated infections in human hospitals and long-term care facilities.[2-5] In these studies, a single day of AU and healthcare-associated infection data are collected from hundreds of facilities and compiled to produce national prevalence estimates. Individual hospitals collect AU data as part of comprehensive institutional AS programs, many reporting AU to CDC's National Healthcare Safety Network Antibiotic Use and Resistance Module, a system that allows hospitals to benchmark AU against that of similar facilities.[6] Animal agricultural AU measurement is conducted by US Food and Drug Administration (FDA), by tracking of sales volumes and collection of AU data for major food animal commodities through cooperative agreements.[7]

There are no standardized efforts to collect national AU data from the US small animal veterinary profession, and robust clinical AS programs are uncommon in individual institutions. However, unnecessary and inappropriate prescribing is likely as common in small animal medicine as in human medicine.[8] A small number of studies have explored this topic, showing that only 20% to 60% of animals receiving an antibiotic prescription have clinical evidence of infection.[9,10] The International Society for Companion Animal Infectious Diseases (ISCAID) has published reports on diagnosis and treatment of superficial bacterial folliculitis in dogs and respiratory and urinary tract diseases in both dogs and cats.[11-13] However, without collection of AU data, there is no way for an individual veterinarian, a veterinary hospital, or the veterinary profession to assess adherence to guidelines, measure improvement, or set broader AS program goals.

The main objective of this study was to estimate prevalence of AU in a single small animal teaching hospital by aggregating data from monthly single-day PPS over the course of 1 year. A secondary objective was to refine standard operating procedures and to develop a data collection tool for use in conducting a national single-day PPS to estimate AU across small animal veterinary teaching hospitals.

2 | MATERIALS AND METHODS

2.1 | Survey setting and materials

The medical records of inpatient and outpatient dogs and cats evaluated during November 2018 to October 2019 on primary and urgent care, emergency and critical care, internal medicine, and surgery services at the University of Minnesota Veterinary Medical Center (UMN VMC) were included in the study. UMN VMC is located in St. Paul, Minnesota, in an urban setting with a population of more than 300 000 residents. The hospital includes 16 specialty services and sees more than 35 000 cases annually.

2.2 | Data collection

Medical record abstraction and data collection were performed by 2 coinvestigators (EH, AM). Clinical records were stratified by antibiotic prescription received (yes or no). A random number generator was used to select 5% of records in which cats and dogs did not receive an antibiotic and 10% of records in which antibiotics were prescribed. These records were validated by coinvestigators (JG, AB) at the 6-month point and again at study completion. Validation consisted of verifying that all variables were consistently entered by all investigators, blinded to each other's responses.

Data were collected for cats and dogs seen on the first Monday of each month for 1 year, except for the first 2 collection months, November and December 2018, and September 2019 (to avoid a holiday) in which data were collected on the first Tuesday of the month. Data collection for March 2019 was shifted to the second Monday of the month because of a hospital-wide transition to a new electronic medical record (EMR) system. All medical records were imported from the previous EMR system to the new EMR system; there were no barriers in collecting the standardized variables defined in the standard operating procedure and data dictionary after the transition. All inpatients present at 4:00 PM CST on each data collection day and seen by a veterinarian working in primary and urgent care, emergency and critical care, internal medicine, or surgery were included in the study.

All outpatients seen by a veterinarian working in primary and urgent care, emergency and critical care, internal medicine, or surgery on the survey date were included in the study. Technician-only appointments were excluded unless a veterinarian subsequently consulted on clinical care after the technician appointment in 1 of the study services. All appointments scheduled from 12:00 AM to 11:59 PM CST on each survey date were included. The census (total number) of cats and dogs seen on each clinical service included in the study was recorded for the entire first week of the month for the first 8 months to understand differences between Monday caseload and other days of the week.

A standard operating procedure and data dictionary, which defined each variable collected, were created to ensure standard collection of data variables. Data abstracted from medical records of dogs and cats included: medical record number, signalment (age, sex, species, and breed), presenting complaint, reason for visit (wellness, sick, surgery or procedure, or recheck) and whether the cat or dog was an inpatient or outpatient. Diagnostics performed were recorded, including bacterial culture and susceptibility (C&S) testing, PCR, serology, and cytology or histopathology. Results from urine sediment analysis, fecal flotation, ear cytology, fluorescein stain, and histopathology were recorded when performed. Test results were recorded, and it was noted if they were available to the clinician on the survey date.

If a cat or dog was prescribed, administered, or currently receiving an antibiotic on the survey date or within 24 hours before the survey date, the antibiotic(s) name, route, and date initiated were recorded, as well as the prescribing service and prescribing clinician type (intern, resident, faculty, or referring veterinarian). Duration data were collected only for antibiotics administered PO and topically and are not described here. Antibiotics initiated by referring veterinarians were recorded if continued by the UMN VMC attending clinician. In the case of long-acting antibiotics (eg, cefovecin), if the antibiotic was still active on the survey date or within 24 hours before the survey date, the antibiotic was included and attributed to the prescribing veterinarian. Antibiotics administered PO during the inpatient stay or prescribed upon discharge of a hospitalized cat or dog receiving IV administered antibiotics were recorded as a separate prescription. In addition to antibiotic prescription details, the study team recorded body system of the primary disease process, or identified the disease as multisystemic, if appropriate, and broad antibiotic indication (ie, cannot be determined from information in medical record, treatment of noninfectious condition, treatment of infection, surgical or procedural prophylaxis, or nonspecific diarrhea). At the time of data collection, the study team categorized the evidence of infection as no evidence of infection, suspected infection, or confirmed infection. Categorization was guided by a standard operating procedure and the data dictionary and based upon available information in the EMR. Only data available on or before the service date was used to determine evidence of infection.

Criteria for "suspected infection," "confirmed infection," and "no evidence of infection" were adapted from a prior study (Table 1).[10] Briefly, if there was no documentation of confirmed or suspected infection or if an alternative noninfectious reason (eg, nonspecific diarrhea) for antibiotic usage was identified, the antibiotic was associated with "no evidence of infection." An antibiotic was associated with "suspected infection" if there were clinical signs of infection without definitive diagnostic confirmation (eg, by cytology, culture). An antibiotic prescription was associated with "confirmed infection" when clinical signs of bacterial infection were supported by site-specific bacterial culture, cytology, or fluid analysis, positive serology, or positive antigen testing.

2.3 | Data analysis

Antibiotic medications administered on the survey date, in the 24 hours before the survey date, or both dates were included in data analysis. For animal-level analysis, antibiotics were considered unique based upon chemical substance, which is consistent with methodologies used in studies to measure human antibiotic use.[2,3] For example, dogs and cats that received 2 formulations of the same drug on the survey date (eg, enrofloxacin administered IV with transition to enrofloxacin administered PO) were considered to have received a single antibiotic drug, and individuals receiving 2 chemically distinct drugs (eg, transition from ampicillin-sulbactam administered IV to amoxicillin-clavulanate administered PO) on the survey date were

TABLE 1 Criteria for level of evidence of infection

Evidence of infection	Criteria
Confirmed bacterial infection	Documentation of positive culture, cytology analysis or fluid analysis with presence of bacteria with clinical signs of infection at the site of collection, positive serology with clinical signs of disease
Suspected bacterial infection	Documentation of open wound with fever, redness, tenderness, warmth, swelling, or bite history, neutrophilic fluid or cytology with no bacteria seen, radiographs identifying pneumonia but without positive airway wash and C&S, purulent skin disease without C&S, purulent discharge from an orifice without C&S, visualization of gastrointestinal perforation in the absence of "confirmed infection," fever of unknown origin, fever with indwelling device (eg, urinary catheter, central line, implant with evidence of infection at the implant site), lytic bony lesion, echocardiographic evidence of vegetative lesion on heart valve
No evidence of bacterial infection	No documentation of confirmed infection or suspected infection, or of an alternative reason for antibiotic. (Includes documented negative titers or cultures, no titers or cultures submitted, "preventative" uses, as written in record, or antibiotics administered systemically after clean surgery.) Alternative noninfectious diagnosis that explains clinical signs

Abbreviation: C&S, culture and susceptibility.

considered to have received 2 antibiotic drugs. The decision to analyze antibiotics as distinct or grouped was based upon peer-reviewed published papers on PPS by the CDC.[2,3] In addition to analysis of distinct drugs, antibiotics were also analyzed by the following drug classes: penicillins, potentiated penicillins, fluoroquinolones, first-generation cephalosporins, third-generation cephalosporins, nitroimidazoles, tetracyclines, sulfonamides, lincomycins, macrolides, amphenicols, and topicals. For a list of antibiotics grouped within each class, see Table S1.

Data were entered and organized in Microsoft Excel version 16.23 and analyses were performed using Excel and SAS (Release 9.4. Cary, North Carolina: SAS Institute, 1997). Descriptive data are presented as frequencies (n) and percentages (%), with missing data excluded. The chi-square test was used to evaluate association between categorical variables.

3 | RESULTS

During the study period of November 2018 to October 2019, a total of 856 cats and dogs were included in the study: 620 (72.4%) dogs and 236 (27.6%) cats. Demographics are summarized in Table 2. The average daily caseload across study services for the 12 survey days was 71.3 dogs and cats. There were no significant differences in caseload between survey dates and other weekdays during the same weeks ($P = .95$). Validation of data entry revealed errors in 3 of the 56 records reviewed. These errors included a medical record number transcription error, an error in recoding clinician type, and an error in recording evidence of infection.

Overall, 249 (29.1%, 95% confidence interval [CI] 26.1%-32.1%) cats and dogs were administered at least 1 antibiotic. This accounted for 310 prescriptions for antibiotic administration. Of 620 dogs, 205 (33.1%) received at least 1 antibiotic, consisting of 98/168 inpatients (58.3%, 95% CI 50.9%-65.8%) and 107/452 outpatients (23.7%, 95% CI 19.8%-27.6%). Among 236 cats, 44 (18.6%) received at least 1 antibiotic, which included 15/49 inpatients (30.6%, 95% CI 17.7%-43.5%) and 29/187 outpatients (15.5%, 95% CI 10.3%-20.7%). The number of antibiotics prescribed for inpatient and outpatient dogs and cats is shown in Table 3. While most inpatients and outpatients were prescribed a single antibiotic, inpatients were more commonly prescribed more than 1 antibiotic than were outpatients. Prescriptions for antibiotics administered systemically were more common than prescriptions for antibiotics administered topically; 27/258 (10.5%) of all antibiotics prescribed to dogs were topical and 11/52 (21.2%) of all antibiotics prescribed to cats were topical.

Differences in the prescribing service between inpatient and outpatient prescriptions were examined. A majority of antibiotics administered to inpatient dogs were administered by 3 services: surgery (63/145, 43.5%, 95% CI 35.4%-51.5%), emergency (39, 26.9%, 95% CI 19.7%-34.1%), and internal medicine (29, 20.0%, 95% CI 13.5%-26.5%), and a majority of antibiotics administered to outpatient dogs were administered by 3 services: urgent care (33/113, 29.2%, 95% CI 20.8%-37.6%), primary care (23, 20.4%, 95% CI 12.9%-27.8%), and

TABLE 2 Dog and cat demographics

	Total count, n = 856 (%)	Dogs, n = 620 (%)	Cats, n = 236 (%)
Sex			
Male neutered	412 (48.1%)	288 (46.5%)	124 (52.5%)
Male intact	48 (5.6%)	42 (6.8%)	6 (2.5%)
Female spayed	361 (42.2%)	265 (42.7%)	96 (40.7%)
Female intact	35 (4.1%)	25 (4.0%)	10 (4.2%)
Species			
Dog	620 (72.4%)	–	–
Cat	236 (27.6%)	–	–
Patient status			
Inpatient	217 (25.4%)	168 (27.1%)	49 (20.8%)
Outpatient	639 (74.7%)	452 (72.9%)	187 (79.2%)
Age			
≤4 months	17 (2.0%)	12 (1.9%)	5 (2.1%)
>4-12 months	51 (6.0%)	33 (5.3%)	18 (7.6%)
>1-3 years	118 (13.8%)	99 (16.0%)	19 (8.1%)
>3-7 years	178 (20.8%)	137 (22.1%)	41 (17.4%)
>7-10 years	177 (20.7%)	137 (22.1%)	40 (17.0%)
>10-15 years	251 (29.4%)	184 (29.7%)	67 (28.4%)
>15-20 years	59 (6.9%)	17 (2.8%)	42 (17.8%)
>20 years	4 (0.5%)	0 (0%)	4 (1.7%)
Missing	1	1	0
Average (years)	7.92	7.35	9.43

internal medicine (21, 18.6%, 95% CI 11.4%-25.8%). Most antibiotics administered to inpatient cats were prescribed by emergency and internal medicine services (7/20, 35.0%, 95% CI 14.1%-55.9% and 7/20, 35.0%, 95% CI 14.1%-55.9%, respectively), and most antibiotics administered to outpatient cats were prescribed in urgent and primary care services (10/32, 31.3%, 95% CI 15.2%-47.3% and 10/32, 31.3%, 95% CI 15.2%-47.3%, respectively).

Of 145 antibiotics administered to inpatient dogs, ampicillin-sulbactam (38, 26.2%, 95% CI 19.1%-33.4%), cefazolin (30, 20.7%, 95% CI 14.1%-27.3%), enrofloxacin (17, 11.7%, 95% CI 6.5%-17.0%), amoxicillin-clavulanic acid (15, 10.3%, 95% CI 5.4%-15.3%), metronidazole (14, 9.7%, 95% CI 4.9%-14.5%), and cephalexin (14, 9.7%, 95% CI 4.9%-14.5%) were the most common (Table 4). Of 113 antibiotics administered to outpatient dogs, metronidazole (24, 21.2%, 95% CI 13.7%-28.8%), amoxicillin-clavulanic acid (20, 17.7%, 95% CI 10.7%-24.7%), cephalexin (13, 11.5%, 95% CI 5.6%-17.4%), and topical gentamicin-betamethasone-clotrimazole (13, 11.5%, 95% CI 5.6%-17.4%) were the most common. Like dogs, ampicillin-sulbactam was the most common antibiotic prescribed to inpatient cats, accounting for 6 of 20 prescriptions (30.0%, 95% CI 9.9%-50.1%). Amoxicillin-clavulanic acid (8/32, 25.0%, 95% CI 10.0%-40.0%) and amoxicillin (4/32, 12.5%, 95% CI 1.0%-24.0%) were the most common antibiotics prescribed to outpatient cats (Table 4).

The antibiotics prescribed for the most common indications, grouped by body system, in cats and dogs is presented in Table 5. Specific diagnoses associated with antibiotic administration to inpatient dogs included lower respiratory tract disease (31/145, 21.4%, 95% CI 14.7%-28.1%), perioperative prophylaxis (22, 15.2%, 95% CI 9.3%-21.1%), orthopedic implants (15, 10.3%, 95% CI 5.4%-15.3%), skin wounds (13, 9.0%, 95% CI 4.3%-13.6%), peritonitis (12, 8.3%, 95% CI 3.8%-11.9%), and nonspecific diarrhea (9, 6.2%, 95% CI 2.3%-10.1%). Nonspecific diarrhea (24/113, 21.2%, 95% CI 13.7%-28.8%), skin

TABLE 3 Number of antibiotic prescriptions per animal

	Dogs (n = 205)				Cats (n = 44)			
	Inpatient (n = 98)		Outpatient (n = 107)		Inpatient (n = 15)		Outpatient (n = 29)	
# of antibiotics	Count	Percent	Count	Percent	Count	Percent	Count	Percent
1	58	59.2% 95% CI 49.5%-68.9%	102	95.3% 95% CI% 91.3%-99.3%	10	66.7% 95% CI 42.8%-90.5%	26	89.7% 95% CI 78.6%-100%
2	34	34.7% 95% CI 25.3%-44.1%	4	3.7% 95% CI 0.1%-7.3%	5	33.3% 95% CI 9.5%-57.2%	3	10.3% 95% CI 0%-21.4%
3	5	5.1% 95% CI 0.8%-9.5%	1	0.9% 95% CI 0%-2.8%	0	0%	0	0%
4	1	1.0 95% CI 0%-3.0%	0	0%	0	0%	0	0%

TABLE 4 Antibiotic drug class prescriptions for inpatients and outpatients

	Prescriptions for dogs (n = 258)				Prescriptions for cats (n = 52)			
	Inpatient (n = 145)		Outpatient (n = 113)		Inpatient (n = 20)		Outpatient (n = 32)	
Antibiotic drug class	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Potentiated penicillins	53	36.6%	21	18.6%	6	30.0%	8	25.0%
Nitroimidazoles	14	9.7%	24	21.2%	2	10.0%	1	3.1%
First-generation cephalosporins	44	30.3%	13	11.5%	3	10.%	0	0%
Topical/otic	1	0.7%	26	23.0%	0	0%	11	34.4%
Fluoroquinolones	19	13.1%	7	6.2%	5	25.0%	2	6.3%
Penicillins	5	3.5%	8	7.1%	2	10.0%	4	12.5%
Tetracyclines	7	4.8%	5	4.4%	1	5.0%	1	3.1%
Lincosamides	0	0%	4	3.5%	0	0%	2	6.3%
Third-generation cephalosporins	1	0.7%	2	1.8%	1	5.0%	1	3.1%
Macrolides	0	0%	2	1.8%	0	0%	2	6.3%
Amphenicols	0	0%	1	0.9%	0	0%	0	0%
Sulfonamides	1	0.7%	0	0%	0	0%	0	0%

wounds (21, 18.6%, 95% CI 11.4%-25.8%), otitis externa (16, 14.2%, 95% CI 7.7%-20.6%), and lower urinary tract infection (10, 8.9%, 95% CI 3.6%-14.1%) were frequent indications for antibiotic administration to outpatient dogs. Among antibiotics administered to inpatient cats, lower urinary tract infection (5/20, 25.0%, 95% CI 6.0%-44.0%) and upper urinary tract infection (4, 20.0%, 95% CI 2.5%-37.5%) were commonly indicated. Lower urinary tract infection (6/32, 18.8%, 95% CI 5.2%-32.3%), upper respiratory tract infection (5, 15.6%, 95% CI 3.0%-28.2%), skin abscess (4, 12.5%, 95% CI 1.0%-24.0%), and superficial corneal ulcer (4, 12.5%, 95% CI 1.0%-24.0%) accounted for over half of antibiotic prescriptions to outpatient cats.

Otitis was the most common reason for prescriptions of antibiotics administered topically for dogs. Of the 17 antibiotic prescriptions for dogs with otitis, all were topical. Similarly, all 3 prescriptions for otitis in cats were topical. The most common reason for prescriptions of antibiotics administered topically in cats was for ocular disease, in which 6/7 prescriptions were topical; in dogs, all (6/6) prescriptions for ocular antibiotics were topical. However, for both cats and dogs, prescriptions of antibiotics for skin conditions were most commonly for systemic administration. Only 4/43 (9.3%) prescriptions of antibiotics for skin disease in dogs were topical and 2/10 (20.0%) for skin disease in cats.

No indication was recorded in the medical record for 11/145 (7.6%, 95% CI 3.3%-11.9%) prescriptions administered to inpatient dogs and 4/113 (3.5%, 95% CI 0.1%-7.0%) prescriptions administered to outpatient dogs. One antibiotic prescription for an inpatient cat had no indication recorded in the medical record (1/20, 5.0%, 95% CI 0%-14.6%); no prescriptions of antibiotics to outpatient cats were missing a recorded indication.

Culture and susceptibility testing was conducted for 57/249 (22.9%) cats and dogs prescribed an antibiotic. Of the 41 C&S tests performed for dogs, 27 (65.9%) had cytology evaluated concurrently and of the 16 C&S tests performed for cats, 13 (81.3%) had cytology evaluated concurrently. Cytology was performed for 98/205 (47.8%) dogs and 28/44 (63.6%) cats that received an antibiotic and for 122/415 (29.4%) dogs and 66/192 (34.4%) cats that did not receive an antibiotic.

TABLE 5 Antibiotics prescribed for common indications

	Prescriptions for dogs (n = 258)	Prescriptions for cats (n = 52)
Skin	Amoxicillin-clavulanic acid: n = 15 (32.6%) Cephalexin: n = 13 (28.3%) Ampicillin-sulbactam: n = 4 (8.7%) Gentamicin/betamethasone/clotrimazole: n = 4 (8.7%) Enrofloxacin: n = 3 (6.5%) Cefpodoxime proxetil: n = 2 (4.4%) Clindamycin: n = 2 (4.4%) Amoxicillin: n = 1 (2.2%) Marbofloxacin: n = 1 (2.2%) Chloramphenicol: n = 1 (2.2%)	Amoxicillin-clavulanic acid: n = 3 (30.0%) Ampicillin-sulbactam: n = 2 (20.0%) Gentamicin/betamethasone/clotrimazole: n = 2 (20.0%) Amoxicillin: n = 1 (10.0%) Clindamycin: n = 1 (10.0%) Marbofloxacin: n = 1 (10.0%)
Respiratory	Ampicillin-sulbactam: n = 17 (43.6%) Doxycycline: n = 7 (17.9%) Enrofloxacin: n = 7 (17.9%) Amoxicillin-clavulanic acid: n = 5 (12.8%) Azithromycin: n = 1 (2.6%) Amoxicillin: n = 1 (2.6%) Ampicillin: n = 1 (2.6)	Amoxicillin-clavulanic acid: n = 2 (33.3%) Azithromycin: n = 2 (33.3%) Doxycycline: n = 1 (16.7%) Enrofloxacin: n = 1 (16.7%)
Gastrointestinal	Metronidazole: n = 34 (94.4%) Sulfadimethoxine: n = 1 (2.8%) Tylosin: n = 1 (2.8%)	Metronidazole: n = 3 (100%)
Urinary	Amoxicillin: n = 6 (46.2%) Amoxicillin-clavulanic acid: n = 3 (23.1%) Enrofloxacin: n = 3 (23.1%) Ampicillin: n = 1 (7.7%)	Amoxicillin: n = 5 (33.3%) Ampicillin-sulbactam: n = 3 (20.0%) Amoxicillin-clavulanic acid: n = 2 (13.3%) Enrofloxacin: n = 2 (13.3%) Marbofloxacin: n = 2 (13.3%) Cefovecin: n = 1 (6.7%)
Perioperative	Cefazolin: n = 19 (86.4%) Cephalexin: n = 3 (13.6%)	Cefazolin: n = 1 (100%)
Aural	Gentamicin/betamethasone/clotrimazole: n = 10 (58.8%) Florfenicol/terbinafine/mometasone: n = 6 (35.3%) Gentamicin/mometasone/clotrimazole: n = 1 (5.9%)	Neomycin/thiobendazole/dexamethasone: n = 3 (100%)

Overall, 48.4% (125/258) of antibiotics administered or prescribed to dogs, and 36.5% (19/52) to cats, had no clinical evidence of infection recorded in the medical record on the study dates. Residents prescribed 38.4% (99/258), faculty 36.0% (93/258) and interns 24.4% (63/258). Residents were also responsible for the highest proportion (45.5%, 45/99) of antibiotic prescriptions in cases lacking evidence of infection compared to faculty (38.7%, 36/93) and interns (30.2%, 19/63).

For prescription of antibiotics in inpatient dogs, 11.7% (17/145, 95% CI 6.5%-17.0%) were prescribed to dogs with confirmed infections, 36.6% (53, 95% CI 28.7%-44.4%) to those with suspected infections, and 51.7% (75, 95% CI 43.6%-59.9%) to those with no evidence of infection recorded in the medical record. Confirmed infections comprised 23.0% (26/113, 95% CI 15.3%-30.8%) of prescriptions of antibiotics to outpatient dogs, suspected infections comprised 32.7% (37, 95% CI 24.1%-41.4%), and those with no evidence of infection comprised 44.3% (50, 95% CI 35.1%-53.4%). Among all prescriptions of antibiotics for dogs lacking evidence of infection, 36.0% (45/125) were for surgical or procedural prophylaxis, while 25.6% (32/125) was for nonspecific diarrhea, 24.0% (30/125) for infection treatment, 8.8% (11/125) could not be determined, and 5.6% (7/125) for nonbactericidal effects of the antibiotic.

Antibiotic prescriptions for inpatient cats were most frequently prescribed to cats with no evidence of infection (10/20, 50.0%, 95% CI 28.1%-71.9%), followed by those with suspected infection (6, 30.0%, 95% CI 9.9%-50.1%) and those with confirmed infections (4, 20.0%, 95% CI 2.5%-37.5%). Among prescriptions of antibiotics to outpatient cats, 34.4% (11/32, 95% CI 17.9%-50.8%) were for cats with confirmed infections, 37.5% (12, 95 CI 20.7%-54.3%) for those with suspected infections, and 28.1% (9, 95% CI 12.6%-43.7%) for those with no evidence of infection. Of the 19 total prescriptions for cats with no evidence of infection, 12 (63.2%) were for infection treatment, 3 each (15.8%) for nonspecific diarrhea and surgical or procedural prophylaxis, and 1 (5.3%) for nonbactericidal effects of the antibiotic.

Evidence of infection (ie, confirmed, suspected, no evidence of infection) for the most common conditions resulting in antibiotic prescriptions for dogs and cats are shown in Figure 1. Among all common indications for administration of antibiotics to dogs, otitis was most likely to be confirmed (12/17, 70.6%), followed by urinary tract infection (7/13, 53.9%). Among all common indications for administration of antibiotics to cats, urinary tract infection was most likely to be confirmed (7/15, 46.7%), followed by skin infections (5/10, 50.0%). Nearly all metronidazole was prescribed without evidence of infection (40/41, 97.6%, 95% CI 92.8%-100%).

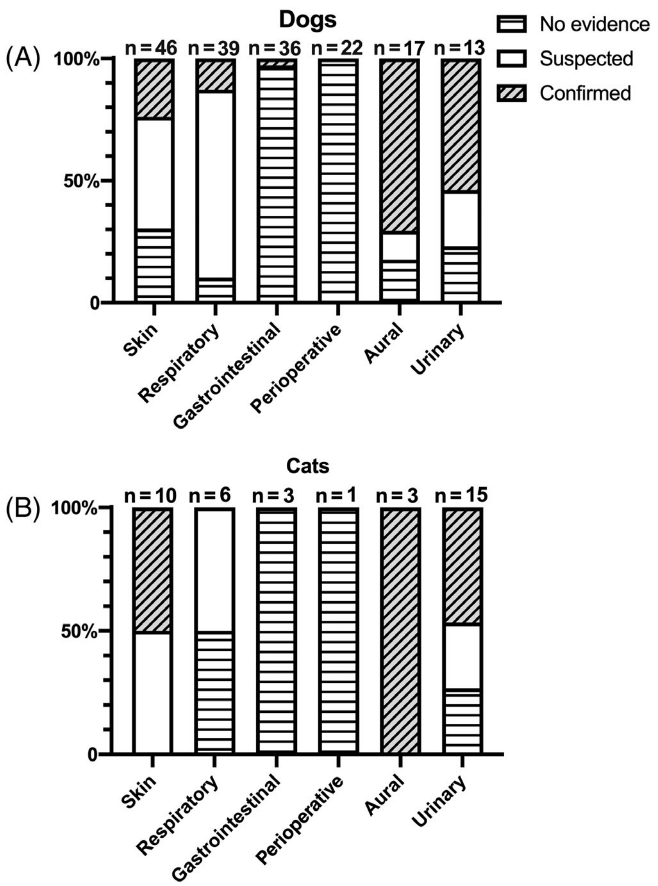

FIGURE 1 Evidence of infection for common antibiotic indications. Evidence of infection among common indications for antibiotic prescriptions, grouped by body system, for cats and dogs is presented. Skin includes superficial, deep, and generalized pyoderma, abscesses, wounds, and anal sacculitis. Respiratory includes upper and lower respiratory tract infections. Gastrointestinal includes acute hemorrhagic diarrheal syndrome, colitis, nonspecific diarrhea, and infectious causes of gastrointestinal signs. Perioperative includes the preoperative, intraoperative, and immediate postoperative periods. Aural includes otitis externa, media, and interna. Urinary includes both upper and lower urinary tract infections

4 | DISCUSSION

In this study, we compiled monthly data to estimate AU prevalence in small animals in a veterinary teaching hospital setting. This approach can be used to identify AS targets. We determined that this method is feasible in a small animal teaching hospital setting for collection and reporting of AU data.

Overall, there was a high frequency of prescription or administration of antibiotics to dogs and cats lacking evidence of infection in the medical record. This was true for nearly half (48.4%) of prescriptions to dogs. We utilized similar criteria to determine level of evidence of infection as another study which found that 38.4% of dogs in a veterinary teaching hospital received an antibiotic administered systemically when there was no documented evidence of infection.[10] The reasons for these findings are likely multifaceted and require further investigation. Motivation for prescribing a clinical course of antibiotics in dogs and cats lacking clear evidence of infection has been a focus of some surveys and qualitative studies of veterinarians. In 1 qualitative study, veterinarians cited clients' lack of willingness or financial ability to perform recommended diagnostic testing, leaving veterinarians to make decisions in the face of diagnostic uncertainty.[14] In a survey of veterinarians in Washington state, cost of bacterial C&S testing was the largest barrier to performing this diagnostic test.[15] Veterinarians might also feel pressure to meet client expectations to prescribe antibiotics, though in some cases client desires are inferred and not stated.[16] Veterinarians have expressed that they perceive no harm in prescribing empirical antibiotics in cases in which the diagnosis was unclear, and for some, the risk of adverse effects does not outweigh the risk of straining the relationship with a pet owner by withholding antibiotics.[14,16] Pet owners generally trust their veterinarians to tend to their pet's needs and prefer administration of antibiotics when their need is uncertain.[17] Antibiotics are commonly used for surgical prophylaxis, both intra- and postoperatively, in animals lacking infection. For some veterinarians, the fear of postsurgical complications guides the decision to prescribe antibiotics.[14] Perisurgical prophylaxis guidance and syndrome-based treatment algorithms in cases of diagnostic uncertainty might aid veterinarians to make more informed prescribing decisions.

Residents had the highest proportion of prescriptions for cats and dogs lacking evidence of infection compared to interns and faculty. It is possible that interns receive more oversight from faculty compared to residents. Faculty might successfully counsel more clients to pursue diagnostic testing. The study design did not allow determination of the reason for these differences. Regardless, targeting residents in hospital AS efforts could improve overall antibiotic prescribing. Medical residents more frequently prescribed in concordance with guidelines when the hospital AS team attended clinical rounds biweekly compared to those residents in which the AS team did not attend rounds.[18]

Data on AU and common indications for prescribing can highlight gaps in clinical practice as well as in availability of professional guidelines. Practice level measurement of AU can allow AS programs to focus on disease or syndrome-specific interventions to improve prescribing. In our study, metronidazole was a commonly prescribed antibiotic for nonspecific diarrhea and was the second most common antibiotic, after cefazolin, prescribed without evidence of infection. Antimicrobial prescribing guidelines are not available for gastrointestinal disease, although they have been published for urinary tract, respiratory and dermatologic disease.[11-13] Lack of consensus on appropriate therapy for acute gastrointestinal disease and nonspecific diarrhea might be a contributor to the considerable volume and nontargeted prescribing of metronidazole measured in this study. Recent evidence suggests that acute diarrhea is self-limiting regardless of antimicrobial therapy, thus highlighting an area within our hospital for AS intervention.[19,20]

Other studies performed in both human and veterinary hospital environments did not capture the use of local antibiotics, including topical, otic, or ophthalmic preparations. This study included those formulations. Antibiotics administered topically are often encouraged as effective alternatives to antibiotics administered systemically, have fewer reported side effects, and are frequently prescribed by general practitioners, dermatologists, and ophthalmologists.[11] Topical and otic preparations accounted for nearly a quarter of antibiotic prescriptions for outpatients in this study. Cephalexin was the most commonly prescribed antibiotic for skin conditions in our study and is a recommended first-tier antibiotic for treatment of known or suspected superficial bacterial folliculitis.[11] It is unknown whether topically administered antimicrobial therapy alone might have been sufficient to resolve some of the skin conditions in this study. This study provides a benchmark that, when the study is repeated, can be used to determine changes in prescribing rates of antibiotics administered systemically versus topically for skin conditions, especially as prescribing guidance is updated.

Additional areas for AS highlighted by our study include the use of cytology for diagnosis of skin infections and the use of antimicrobial therapy administered topically over systemically. A large majority of antibiotics intended to treat skin disease, including abscesses, pyoderma, or wounds, were prescribed for suspected infection or when there was no evidence of infection. Largely, no confirmatory testing (cytology or bacterial culture) was conducted when antibiotics were used to treat skin infections, but most cats and dogs treated with antibiotics for otitis had confirmatory testing performed. While the data collected in this study cannot assess the potential impact that cytology might have had on prescribing for skin infections, ISCAID guidelines for treatment of superficial bacterial folliculitis in dogs highlight the value of cytology and strongly recommend its use as an adjunctive diagnostic test for proper diagnosis.[11]

Urinary tract infections in cats are uncommon, thus guidelines suggest a diagnostic work-up be undertaken for cats with lower urinary tract signs to look for nonbacterial causes of disease.[13] In this study, over half of cats prescribed an antibiotic for urinary tract disease did not have a confirmed bacterial infection (ie, no urinalysis or C&S testing). Though, the reason for lack of testing is unknown, a potential AS goal for this teaching hospital would be to encourage urinalysis and C&S in cats with urinary tract signs and coach clinicians in client education to make uptake of these recommendations more likely.

Antimicrobials considered to be first-tier choices for veterinary practice, including amoxicillin, amoxicillin-clavulanic acid, and cephalexin, were among the most common prescriptions in this study.[21] Enrofloxacin, a second-tier antibiotic, was also frequently prescribed. Third-generation cephalosporins (ie, cefovecin, cefpodoxime proxetil) were prescribed for 5 cats and dogs, none of which had confirmed infections. The low frequency of third-generation cephalosporin use in this study sample is likely related to UMN VMC protocols discouraging use, including retrospective audit and feedback when cefovecin is administered. This is unlikely to reflect practices in most primary care clinics and, perhaps, in other veterinary teaching hospitals. Cats are frequently prescribed third-generation cephalosporins in primary care settings.[9,22]

This study had several limitations. The primary goal of the study was to understand antibiotic prescribing rates and common indications in a small animal veterinary teaching hospital. Given study design, clinical outcomes could not be determined from this data set. Additionally, while indication for prescriptions of antibiotics were recorded, diagnosis was not recorded for animals that did not receive a prescription of antibiotics. This precluded us from reporting on the rates of antibiotic prescribing for specific conditions and is a goal of future studies. Finally, the results of this study, of a single teaching hospital, cannot be extrapolated to broader samples. Geographic differences have been noted in human outpatient prescribing across the United States and have been used to target AS interventions.[23] The secondary objective of this study was to develop a data collection tool and standard operating procedures for a national single-day AU PPS of veterinary teaching hospitals, which is now underway. The coauthors consider this an important first step in establishing a national-level understanding of AU in small animal veterinary practice.

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CONFLICT OF INTEREST DECLARATION

Authors declare no conflict of interest.

OFF-LABEL ANTIMICROBIAL DECLARATION

Authors declare no off-label use of antimicrobials.

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Authors declare no IACUC or other approval was needed.

HUMAN ETHICS APPROVAL DECLARATION

Authors declare human ethics approval was not needed for this study.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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