

Evaluation of Antimicrobial Opinions and Uses in Small and Large Animal Veterinary Practice in
Washington State

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Abstract

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Antimicrobial resistance in bacteria has been a prominent topic of concern for the public health sector in the 21st century. While there are many factors that contribute to increasing AMR in the human population, antimicrobial use in companion animal and large animal veterinary practices is of particular interest due to the One Health paradigm. Understanding antimicrobial prescription habits in veterinary medicine can help to characterize the impacts of regulations and other interventions currently used in veterinary medicine to reduce unnecessary antimicrobial prescription and the potential development of resistant pathogens.

A survey was designed and made available to Washington State practicing veterinarians during the time period of February 8, 2023 to March 31, 2023. The survey consisted of three sections designed to evaluate antibiotic prescription tendencies and general opinions regarding antimicrobial stewardship in veterinary medicine. Hypothetical clinical scenarios were created to inquire about antibiotic usage in common clinical situations in small, mixed, and large animal veterinary practice in Washington state.

In total, 54 veterinarians completed the survey including 46 small animal veterinarians, 17 mixed animal vets, and 15 large animal vets. We evaluated correctness of antibiotic usage judgments for the scenario-based questions. Results showed an approximately 62% correct response rate for small animal veterinarians and an approximately 32% correct response rate for mixed animal veterinarians, and approximately 45% correct response rate for large animal veterinarians. When asked which factors in veterinary medicine may contribute or play a role in an antimicrobial resistance, 85% selected owner/producer compliance, 78% selected veterinary medicine prescription practices, 78% selected prescription of broad-spectrum antimicrobial drugs for treatment, and 50% selected lack of veterinary education on antimicrobial use and stewardship. Finally, a majority of participants (70%) agreed that client finances influence the manner they prescribe antimicrobials, and a majority of participants stated that client expectations of receiving antimicrobials does not influence the manner in which they prescribe.

These findings emphasize the importance of continued efforts to promote responsible use of AMDs in veterinary medicine practice, including improved training through continuing education opportunities, intuitive stewardship, resources, and the implementation of guidelines and regulations to ensure that AMDs are used judiciously.

Introduction

Antimicrobial resistance (AMR) in bacteria has been a prominent topic of concern for the public health sector in the 21st century (1). According to the CDC, around 3 million antimicrobial-resistant infections occur in the United States each year in humans, with an estimated \$4.6 billion spent annually to treat infections caused by these resistant microbes (2). While there are many factors that contribute to increasing AMR in the human population, antimicrobial use in companion animal and large animal veterinary practices is of particular interest (3).

Antimicrobial resistance in animals does not solely impact animal health and can have an impact on human public health, through sharing of antimicrobial resistance and potential food insecurities if herd health cannot be managed due to AMR (4). In veterinary medicine, current federal regulations regarding antimicrobial use play a role in prescription patterns through the Animal Medicinal Drug Use Clarification Act (AMDUCA) (5). The focus of regulation falls on large animal medicine with prohibition of AMD use for growth promotion, and restrictions requiring adherence to on-label use

for specific drug classes (6,7). For example, chloramphenicol has no label indication and therefore is prohibited from use, fluoroquinolones are restricted to label indications with no exceptions and cephalosporins are restricted to production class, label

dose, route and frequency but may be used for other indications beyond the label (8). For small animal care, there are no off label prohibitions, which may result in critically important human drugs being used in small animal care (9). Antimicrobials used to treat animals can apply a selective pressure for the emergence of resistant bacteria that can then be transferred to

Study Impacts:

1. Understanding prescription patterns of Washington state veterinarians is important from a One Health and human public health perspective.
2. Improved understanding of antimicrobial drug use can help to improve prescription practices in Washington State by highlighting areas for improvement.
3. Identifying areas for improvement can be used to develop intuitive outreach for the Washington state veterinary community.

humans (10, 11). This can especially be true when antimicrobials are incorrectly prescribed, or treatment plans are not correctly followed (10). The connection between human and animal health makes understanding antimicrobial prescription patterns in veterinary medicine beneficial for both human and animal health (12).

Various veterinary species suffer from diseases that are often treated with antimicrobial drugs (AMD) (13). Diseases common in cattle include pneumonias, diarrhea, mastitis, reproductive infections and pododermatitis (13). For dogs, these diseases include dermatitis, otitis, diarrhea and upper respiratory infections (14). For cats, these common diseases include feline lower urinary tract disease (FLUTD), upper respiratory tract infection, diarrhea and dental disease (14). Given the treatment of these animal diseases with AMDs, the potential effects on animal populations will only grow in importance and relevance to the health of said populations (15).

Antimicrobial stewardship refers to interventions aimed to improve and quantify the appropriate use of antimicrobials by promoting the optimal antimicrobial drug regimen (16). This optimal drug regimen includes correct dosing, duration of therapy and route of administration (16). In human care, antimicrobial stewardship efforts have been implemented and studied extensively. A study surveying nationwide antimicrobial stewardship practices in health care providers found that half of respondents had formal antimicrobial stewardship plans, and that common barriers to these plans included funding and staffing constraints (16). An additional study prospectively evaluated impacts of a comprehensive antimicrobial stewardship program on AMD use, physician interventions, patient outcomes and rates of AMR in a children's hospital found that the successful implementation of these strategies had a significant impact on reducing targeted and non-targeted AMD use (17). In veterinary care, a strong example of veterinary stewardship work has occurred within the state of California, where resources are provided to farm workers and veterinarians such as antimicrobial stewardship booklets, and information about the treatment of specific animal diseases (18).

Additionally, recent surveys in the Western US have evaluated efforts in veterinary stewardship (19, 20). In Colorado, the Colorado Integrated Food Safety Center of Excellence (CoE) carried out a questionnaire that focused on surveying large animal veterinarians across the United States (19). The authors found that most of the study participants would recommend AMD treatment for an individual ill animal but saw variation for group large animal setting scenarios (19). An additional study from the Colorado Center of Excellence focused on small animal veterinarians in the United States (20). This survey found that antimicrobial drugs were commonly recommended in the five hypothetical practice scenarios, and that prescribers who reported an awareness of existing antimicrobial use guidelines were significantly less likely to recommend antimicrobial treatment for certain scenario-based questions (20). Both surveys used scenario-based questions to gather data on prescription practices, tendencies, and opinions of veterinarians.

Understanding antimicrobial prescription habits in veterinary medicine can help to characterize the impacts of regulations and other interventions currently used to reduce unnecessary antimicrobial prescription and the potential development of resistant pathogens (21). The purpose of this study is to assess opinions and use patterns of small, mixed, and large animal veterinarians to determine factors that impact their prescription of AMDs and knowledge gaps in their judicious AMP practice. Results and subsequent analysis of this survey will be used to develop effective educational resources and more intuitive stewardship for veterinarians in Washington State.

Methods:

Survey Development, Question Examples, Survey Distribution

An anonymous survey was designed and released to Washington State practicing veterinarians during the time period of February 8, 2023 to March 31, 2023. The questionnaire disseminated in the current study combines principles and content from each of the two Colorado CoE surveys, with branching logic questions. As participants select the species they

treat, questions relating to those specific animals propagate. These questions presented scenarios that are commonly encountered in Washington State veterinary practice and were created in collaboration with a resident veterinarian and the Washington State University Veterinary Extension. The current study was disseminated to veterinarians practicing in Washington State.

This survey was disseminated through communications from the WVSMA, Washington State University Veterinary School, King County Veterinarian Updates email list, and through social media recruitment. Participants self-selected into the study by filling out a pre-screening and consent form. The pre-screening form confirmed the participant was a practicing veterinarian in Washington State, and asked how the participant found the survey. Sample size was determined based upon the number of participants that completed the survey.

The survey in the current study builds upon principles from the Colorado surveys but incorporates new innovative questionnaire design. In our survey, participants select the species they treat, questions relating to those specific animals propagate, and depending on answer selections in the scenario question, specific follow up questions would be presented. The survey's content differs from Colorado because it presents an example diagnostic test and result, and employs branching logic to do so. These questions presented scenarios that are commonly encountered in Washington State veterinary practice and were created in collaboration with a resident veterinarian and the Washington State University Veterinary Extension. Through screening criteria, the current study was disseminated only to veterinarians practicing in Washington State.

The survey consisted of three sections. The first section contained demographic questions, the second section asked about factors influencing AMP, and the third section included hypothetical situational questions. The scenarios were created to reflect common clinical situations in small, mixed, and large animal veterinary practice in Washington State, as determined through coordination with the Washington State Animal Disease Diagnostic

Laboratory. The species included were cats, dogs, backyard goats, backyard chickens, commercial poultry, horse, beef cattle, and dairy cattle. Participants selected species they treat in their practice, which determined the hypothetical scenario questions received. Answer selections subsequently propagated specific follow up questions in the survey. If a veterinarian chose to prescribe empiric antimicrobial therapy, they were asked which antimicrobial they would prescribe for the given situation. If a veterinarian chose to prescribe AMDs while awaiting diagnostic results or to prescribe AMDs after diagnostic testing, they would be presented with hypothetical culture results and asked which, if any, antimicrobial they would prescribe given the results. All participants selected AMDs from a list of antimicrobials designed to mimic those provided by large diagnostic laboratories. Some scenarios for large animal veterinarians were herd-based, where a portion of the herd presented with symptoms, and asked which treatment (individual or all) a participant would prescribe.

The factors influencing prescription section asked questions regarding influences, perceptions, and opinions. These questions were designed to inform intuitive resources on AMD prescription in the future.

Analysis of Survey Responses

For analysis of survey results, only responses that answered the majority of questions were included, meaning if a participant filled out the consent form, opened the survey questions and answered no questions, their response would not be included in the data set. Of the 72 surveys responses received, 18 were discarded because no questions on the survey were completed, leaving 54 survey responses for our analysis (Figure S1). Correct treatment choice for each situational question was decided upon through consultation with the resident veterinarian and the Washington State University Veterinary Extension, who helped to design the survey. For large animal situation-based questions, veterinarians were asked if they would contact the state veterinarian's office.

Survey data were downloaded from Red Cap and imported into R (version 4.1.1). The data were processed by simplifying free response questions, and by filtering types of veterinary responses by species that the respondents listed they treated using *dplyr* (1.1.1). Because most respondents were small or mixed animal veterinarians, an additional metric was made for small and mixed animal scenario-based questions, which was a total score (sum of correct responses). Linear regressions using the *lm* package (4.1.1) were used to assess the association between usage opinions (from the factor-based questions) and total score. Chi-squared tests were used to determine the association between AMR factors and correctness of individual questions. Chi square analysis assessed the association between choosing a correct answer for a scenario-based question, and selecting a given answer option for the opinion-based questions. Linear regression analysis assessed the association between choosing a correct answer for the scenario based question, and the option selected for the Likert scale questions. Linear regression was also conducted to assess associations between summation scores on the scenario questions for small and mixed animal veterinarians and whether or not the participant selected an answer option for the perception and opinion-based questions, as well as selections for the Likert scale questions. Opinions of interest for the linear regressions and chi-squared tests were factors that veterinarians believe may play a role in antimicrobial resistance, veterinary antimicrobial use guidelines typically referred to in practice, and whether or not factors such as client expectations, finances, and ability to dispense impacted the manner in which veterinarians prescribed AMDs. Opinion questions regarding client characteristics were based upon a Likert scale. This scale was adjusted from five categorical options to three categorical options during data analysis, in order to better see trends in our data. P-values were corrected for multiple hypothesis testing using the Bonferroni method (22).

Results

Survey responses

Because the survey was disseminated through email listservs and social media recruitment, it was not possible to calculate a response rate for the survey. However, the size of the WSVMA mailing list is approximately 4,150 veterinarians. When processing survey responses for analysis, 18 of the 72 survey responses were incomplete, with no questions filled out, and not incorporated into the final dataset used for analysis. A flow diagram depicting this exclusion process is included in Figure 1 of the Supplemental Information. 54 complete survey response records were used for analysis including 49 small animal veterinary respondents, 17 mixed animal veterinary respondents, 6 large animal respondents (1 feedlot cattle and 5 dairy cattle), and 1 commercial poultry respondent.

Demographics Information

Of the 54 responses, 50% (27) of respondents attended veterinary school within the Washington COE region, and the remaining 50% attended vet school in a variety of COE regions, including Minnesota, Colorado, New York, and Tennessee (Table 1). Integrated Food Safety Centers of Excellence (Food Safety CoEs) is a program developed in 2012 by the CDC to assist and bolster local health departments in their capacity to combat enteric diseases in their specific regions by administering training and peer communication (23). The experience veterinarians had in clinical practice varied across all answer options provided with the majority of respondents having more than 20 years of clinical experience (52%, 28 respondents), 9% of respondents had 16-20 years of experience (5 respondents), 17% of respondents had 11-15 years of experience (9 respondents), 9% of respondents had 5-10 years of experience (5 respondents), and 13% of respondents had less than 5 years of experience (7 respondents). In general don't just read the table into the text, instead provide a guide/overview to interpreting it.

Table 1: Demographics information for all survey responses received.

Demographic Variables	Number of Respondents (%)
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COE Region of Vet School Attended	
Washington	27 (50)
Minnesota	9 (17)
Colorado	6 (11)
New York	6 (11)
Tennessee	2 (04)
Other	4 (07)
Clinical Practice Experience Time	
Less than 5 years	7 (13)
5-10 years	5 (09)
11-15 years	9 (17)
16-20 years	5 (09)
More than 20 years	28 (52)
Type of Veterinarian	
Small	38 (70)
Mixed	11 (20)
Large	5 (09)
Species Treated	
Dog	46 (85)
Cat	49 (91)
Backyard	17 (31)
Commercial Poultry	1 (02)
Commercial Dairy	6 (11)
Commercial Feedlot	2 (04)
Equine	8 (15)
Packet/Exotic	19 (35)
Wildlife	8 (15)
Other	6 (11)
Practice Role	
Owner	22 (41)
Associate	21 (39)
Locum	3 (06)
Other	8 (15)
Sector	
Private Practice	34 (63)
Corporate Practice	17 (31)
Government	0 (0)
Industry	1 (02)
Academic	5 (09)
Other	3 (06)

Small, mixed large animal veterinary and scenario-based sections

For the small animal survey questions, 51% (23/45) of respondents answered the cat UTI scenario correctly, 72% (33/46) answered the dog gastrointestinal scenario correctly, and 67% (30/46) answered the kitten respiratory scenario correctly (Table 2). When antimicrobials were prescribed, the most common antimicrobial prescribed for the cat case was amoxicillin, the most

common antimicrobial prescribed for the dog case was amoxicillin, and the most common antimicrobial prescribed for the kitten case was doxycycline. Overall, across all small animal questions, amoxicillin was prescribed most often, followed by doxycycline and cefovecin. For all three small animal scenario-based questions, antimicrobial prescription is not the most preferred treatment plan. For the cat case, the frequency of antimicrobial prescription when not recommended was 11% (8/76). For the dog case, the frequency of antimicrobial prescriptions when not recommended was 24% (14/58). For the kitten case, the frequency of antimicrobial prescriptions when not recommended was 15% (9/59).

In the mixed animal practice veterinarian questions, 33% (5/15) and 38% (6/16) respectively answered correctly for scenarios of the goat with a submandibular abscess and backyard chicks with respiratory symptom. For the backyard goat question, the initial scenario and culture results described did not necessitate AMP. In total, 10/15 (67%) participants elected to treat with antimicrobials for this scenario when not needed while 100% of participants who received the follow-up prompt prescribed antimicrobials as necessitated by the results of the test. When antimicrobials were prescribed, the most common antimicrobial prescribed was penicillin followed by sulfadiazine and ceftiofur. For the initial prompt in the backyard chicken scenario question, antimicrobial prescription was not the preferred treatment plan while the follow-up question gave test results that necessitated antimicrobial prescription. In total, 6/12 (50%) participants elected to treat with antimicrobials for this scenario when not needed, while 100% of participants who received this prompt prescribed antimicrobials as necessitated by the results of the test. When antimicrobials were prescribed, tylosin tartrate was most commonly used.

The survey collected five dairy cattle veterinarian responses. For the first scenario, a group of Holstein heifers of weaning age are to be moved to a grow barn. One respondent recommended empiric antimicrobial therapy to cattle showing symptoms and recommended the antimicrobial florfenicol. The other three respondents recommend non-antimicrobial treatments,

which was the correct treatment plan according to the project veterinary experts. For the second scenario, a Holstein heifer presents with lethargy, isolation, diarrhea and fecal staining of hind legs, and a fever. Responses were varied with all participants selecting different treatment plans. One participant elected to treat with empiric antimicrobial therapy with no testing and prescribed the antimicrobial ceftiofur. One participant elected empiric antimicrobial therapy, while awaiting results from the lab. This participant prescribed ceftiofur and did not change their prescribing regimen after reading testing results. One respondent elected to wait for test results to prescribe antimicrobials, and after receiving the fecal sample test results, which showed *Salmonella Typhimurium* and bovine coronavirus, prescribed ceftiofur. One respondent elected a non-antimicrobial treatment plan. The third scenario describes a subset of recently weaned heifers showing signs of respiratory disease, dehydration, and a fever. Two heifers have died; one necropsy revealed fibrinous pneumonia and another showed effusive pleuritis. For this scenario, all five respondents elected empiric antimicrobial therapy to only cattle showing symptoms, and all respondents except one selected the antimicrobial tulathromycin. After receiving results from a test where *Histophilus somni* and *Mycoplasma bovis* were identified, three respondents did not change the treatment plan and one respondent elected to change the antimicrobial prescription to gamithromycin. Responses to the fourth scenario, a dairy cow experiencing mastitis, varied as well. One respondent recommended empiric antimicrobial therapy of cephapirin sodium and stopped antimicrobial therapy after receiving test results. Two respondents recommended antimicrobial prescription after reviewing test results. After seeing test results, one respondent prescribed ceftiofur sodium, and another respondent elected to not prescribe antimicrobials. One respondent recommended non-antimicrobial treatment for this scenario, which was the most preferable treatment plan.

For the equine scenario questions, 12.5% (1/8) and 63% (5/8) of participants answered the first and second questions correctly. Although antimicrobial prescription was not the preferred answer for the horse with respiratory symptoms, 7/8 (88%) participants elected to treat

with antimicrobials. Amoxicillin/clavulanic acid, penicillin, and trimethoprim/sulfamethoxazole were prescribed. In the case with diarrheal symptoms, antimicrobial prescription was not the preferred treatment plan. 6/11 (55%) participants elected to treat with antimicrobials and the two antimicrobials prescribed were ampicillin/sulbactam and trimethoprim/sulfamethoxazole.

Table 2: Summary of results for small animal, mixed animal and equine scenario

questions. The number of correct and incorrect is the number of correct responses to the initial scenario-based question. For the prescription of antimicrobials whether preferred or unpreferred, the number of prescriptions is calculated from selection of antimicrobial treatment plan for initial scenario-based questions and subsequent branching logic questions.

Species	% of Correct Responses (n)	% of AMD prescriptions when preferred (n)	% of AMD prescriptions when unpreferred (n)
Small Animal			
Cat Case	51 (23)	N/A	11 (8)
Dog Case	72 (33)	N/A	24 (14)
Kitten Case	65 (30)	N/A	15 (9)
Backyard Animals			
Backyard Chicken	38 (6)	100 (1)	50 (6)
Goat Case	33 (5)	100 (1)	67 (10)
Equine			
Horse 1 Case	13 (1)	17 (1)	88 (7)
Horse 2 Case	63 (5)	N/A	67 (10)

Perceptions, attitudes and opinions

For the opinion question about which factors contribute most to antimicrobial resistant infections in humans, 49 respondents (91%) selected antimicrobial use in human medicine, 34 respondents (63%) selected antimicrobial use in small animal veterinary medicine, and 44 respondents (81%) selected antimicrobial use in food animal medicine (Table S1).

Environmental pressure and random genetic mutations were both selected by 29 respondents (54%). When asked which factors in veterinary medicine may contribute or play a role in an antimicrobial resistance, 46 respondents (85%) selected owner/producer compliance, 42 (78%) selected veterinary medicine prescription practices, 39 (78%) selected prescription of broad-spectrum antimicrobial drugs for treatment, and 27 (50%) selected lack of veterinary education on antimicrobial use and stewardship.

When asked which veterinary antimicrobial use guidelines typically referred to in practice, organizational antimicrobial use guidelines-such as AVMA, AAHA or ISCAID- were selected by 37 of the respondents (69%). Personally developed antimicrobial use guidelines were selected by 24 (44%) respondents and hospital specific antimicrobial use guidelines was the next most selected use guidelines (13%) (Table S1). Additional information on answers to opinion-based questions broken down by species treated are included in the Supplemental Information (Table S2, S3, S4, S5).

Finally, we asked veterinarians about client-based factors such as client expectations of receiving antimicrobials, client ability to medicate and client finances. A majority of participants(70%) agreed that client finances influence the manner they prescribe antimicrobials, and a majority of participants stated that client expectations of receiving antimicrobials does not influence the manner in which they prescribe (Table S6). Breakdowns of Likert scale question results by species treated are also included in the Supplemental Information (Table S7, S8, S9, S10).

There was a significant association between selecting the opinion that “antimicrobial drugs available on site plays a role in antimicrobial resistance” and answering the cat UTI scenario correctly, although not significant when correcting for multiple comparisons (corrected p-value=0.06; Table 3 and Table S11). Additionally, for the summation score for small animal scenarios, there was a significant association between selecting “antimicrobial drugs available on site plays a role in antimicrobial resistance” and scoring higher on small animal scenario-

based questions, although not significant when correcting for multiple comparisons (corrected p-value=0.15). There was a significant association among the mixed animal vets between selecting that “client expectations plays a role in emergence of antimicrobial resistance” and scoring higher on mixed animal scenario-based questions, although this was not significant when correcting for multiple comparisons (corrected p-value =0.06; Table 3 and Table S10). No significant associations were found when looking at the impact of veterinary antimicrobial use guidelines (Table 4 and Table S12).

Table 3: Association between which of the following factors plays a role in antimicrobial resistance and answers to each scenario question for small and mixed animal veterinarians. Chi-squared tests were used for individual scenario questions and linear models were used for associations with total score.

	Owner/producer compliance		Veterinary medicine prescription practices		Client expectations		Prescription of broad-spectrum antimicrobial drugs for treatment		Financial constraints		Restrictions of owner (For example: time available to administer treatment, etc)		Antimicrobial drugs available on site		Lack of veterinary education on antimicrobial use and stewardship	
	Statistic	p-value	statistic	p-value	statistic	P-value	statistic	p-value	statistic	p-value	statistic	p-value	statistic	p-value	statistic	p-value
Small animal																
Kitten case	0.0 (1, 46) ¹	1.0	0.08 (1, 46)	0.77	1.25 (1, 46)	0.26	0.18 (1, 46)	0.67	2.40 (1, 46)	0.12	0.01 (1, 46)	0.92	0.31 (1, 46)	0.58	0.10 (1, 46)	0.76
Dog case	0.04 (1, 46)	0.85	0.001 (1, 46)	0.97	0.0 (1, 46)	1.0	0.15 (1, 46)	0.70	1.72 (1, 46)	0.19	0.71 (1, 46)	0.40	1.55 (1, 46)	0.21	0 (1, 46)	1.0
Cat case	0.25 (1, 46)	0.62	0.67 (1, 46)	0.41	0.18 (1, 46)	0.67	1.14 (1, 46)	0.29	0.20 (1, 46)	0.66	0.20 (1, 46)	0.66	5.23 (1, 46)	0.02*	0.20 (1, 46)	0.66
Summation score	0.06 (0.36) ²	0.86	0.27 (0.30)	0.36	-0.09 (0.25)	0.71	0.46 (0.25)	0.07	0.05 (0.24)	0.84	0.23 (0.24)	0.35	0.47 (0.24)	0.05*	NA	NA
Mixed animal																
Goat case	NA ³	NA	0.0 (1, 15)	1.0	4.05 (1, 15)	0.04	0.04 (1, 15)	0.85	0.0 (1, 15)	1.0	0.84 (1, 15)	0.36	0.033 (1, 15)	0.85	0.04 (1, 15)	0.85
Backyard chicken case	NA	NA	0.17 (1, 16)	0.90	0.27 (1, 16)	0.61	0.64 (1, 16)	0.42	0.27 (1, 16)	0.61	0 (1, 16)	1.0	0.83 (1, 16)	0.36	0.48 (1, 16)	0.49
Summation score	NA	NA	0.11 (0.39)	0.78	0.84 (0.30)	0.02*	.50 (0.38)	0.21	0.23 (0.37)	0.54	0.23 (0.37)	0.54	0.50 (0.35)	0.18	0.10 (0.40)	0.81

- ¹: Chi-squared statistic (degrees of freedom, N)
- ²: Estimate (standard error)
- ³: Too sparse to model
- *: p-value <0.05

Table 4: Association between veterinary antimicrobial use guidelines used and answers to each scenarios question for small and mixed animal veterinarians. Chi-squared tests were used for individual scenario questions and linear models were used for associations with total score.

	Organizational antimicrobial use guidelines (i.e., AVMA, AAHA, ISCAID)		Hospital-specific antimicrobial use guidelines		Personally developed antimicrobial use guidelines		I generally do not refer to antimicrobial use guidelines during my practice	
	Statistic	p-value	statistic	p-value	statistic	P-value	statistic	p-value
Small animal								
Kitten case	0.0 (1, 46) ¹	1.0	0.0 (1, 46)	1.0	0.83 (1, 46)	0.36	0.46 (1, 46)	0.50
Dog case	0.09 (1, 46)	0.76	0.23 (1, 46)	0.63	0.58 (1, 46)	0.45	0.21(1, 46)	0.65
Cat case	0.0 (1, 46)	0.62	0.79 (1, 46)	0.38	0.0 (1, 46)	1.0	0.0 (1, 46)	1.0
Summation score	0.09 (0.28) ²	0.74	-0.38 (0.33)	0.26	0.37 (0.24)	0.12	0.83 (0.47)	0.08
Mixed animal								
Goat case	1.84 (1, 15)	0.18	0.0 (1, 15)	1.0	0.04 (1, 15)	0.85	0.07 (1, 15)	0.79
Backyard chicken case	0.07 (1, 16)	0.79	0.07(1, 16)	0.79	0.17 (1, 16)	0.68	1.37 (1, 16)	0.24
Summation score	0.20 (0.39)	0.62	0.29 (0.75)	0.71	-0.66 (0.38)	0.11	0.31 (0.55)	0.58

- ¹: Chi-squared statistic (degrees of freedom, N)
- ²: Estimate (standard error)

Discussion

Our survey to assess prescription patterns of veterinarians and factors that influence this found trends of varied agreement on treatment plans, and important determinants of usage pertaining to how client characteristics, such as ability to medicate or finances, influence veterinarian prescription habits. Additionally, we also found important results regarding what guidelines veterinarians are following in their practice, which may have implications for the level of correctness we saw for the scenario-based questions. We further found little correlation between types of guidelines referenced in practice and clinical antimicrobial judgements for our scenario-based questions. These results have implications for stewardship to the WA state veterinary community and emphasize the necessity of resources detailing case definitions for diagnosis and defined treatment protocols, to encourage adherence to judicious use practices with the narrowest spectrum drug available and with support of diagnostics.

Using antimicrobials judiciously is important, to avoid an animal's unnecessary exposure to unneeded antimicrobials, thus preserving AMDs' effectiveness (24, 25). When looking at the branching logic questions alongside the initial scenario question, frequency of antimicrobial prescription when not recommended ranged from approximately 10% to 25% for small animal questions. For mixed animal, the frequency of prescription when not needed was approximately 50-55%. For equine questions, prescription when not necessitated was 55% and 88% for each question respectively. These results illustrate a trend in the prescription practices of small, mixed and equine veterinarians where antimicrobials are selected as the treatment plan when not necessitated. For One Health, this misuse of antimicrobials and subsequent development of resistance can contribute to the overall burden of AMR in the broader ecosystem, including humans. Inappropriate prescription leading to an increase in antimicrobial resistance could also result in more ineffective treatments, which could lead to treatment failure, and increased sickness time or morbidity in animals (25, 26). This can increase economic consequences

across all types of veterinary practice for owners and producers, as well as impact food security for the human population (27, 28, 29). By understanding rates of inappropriate antimicrobial prescription, we can identify areas where interventions could improve prescribing practices and promote appropriate use of antimicrobials.

Responses to scenario-based questions were varied, with low consensus amongst participants regarding the correct answer. For small animal veterinarians, correctness for the three situational questions ranged from approximately 50% to 70%. For mixed animal veterinarians, correct answers for initial scenario questions were chosen 35% of the time. For equine, correctness for the first scenario was 13%, and correctness for the second scenario was 63%. Understanding rates of inappropriate AMPs can provide a basis for and help to assess overall effectiveness of stewardship efforts (30). This variation in responses and correctness for the scenario-based questions emphasizes the need for resources detailing case definitions for diagnosis and defined treatment protocols.

In addition to over prescription, use of broad-spectrum drugs when more specific options are available can be problematic. An example of broad-spectrum drug usage that was particularly prevalent for results in our survey was the prevalence of prescription of ceftiofur. Ceftiofur was prescribed by at least one respondent in 3/4 dairy scenario-based questions, and by one respondent to treat the submandibular abscess in goats. In small animal veterinary practice, broad-spectrum antimicrobials are commonly used as well. A study investigating antimicrobial usage and AMR in companion animals reported that broad-spectrum antimicrobials and critically important antimicrobials for human medicine represented 83% and 71% of the total number of treatments given to dogs and cats (29). In our survey we saw similar results, with broad-spectrum antimicrobials being prescribed 72% of the time across all three small animal scenarios. Cephalosporins were also prescribed with 27% frequency in small animal scenario responses, with ceftiofur the most prescribed of this group.

Ceftiofur is a 3rd generation cephalosporin antimicrobial that is commonly prescribed due to its broad-spectrum activity, its availability in a variety of formulations, and relatively short withdrawal time (31). This class of drugs are classified as critically important for human medicine by the World Health Organization due to its importance for treating serious infections in humans (32). Preserving cephalosporin efficacy is important, because development of resistance to this class of drugs in animals could be transmitted to humans and impact public health (33). These trends of cephalosporin prescription across small and large animal veterinarians emphasize the necessity of outreach to veterinarians in Washington, to address the use of this drug class in their practice and to begin a conversation on how best to support veterinarians in their usage of this drug class.

Our results demonstrated that client finances have a potential to influence prescription patterns of veterinarians. Across all veterinarians in our survey, 73% stated that client finances influenced the manner in which they prescribe antimicrobials. Financial constraints of clients and/or producers may contribute to the over-prescription of antimicrobials; if clients are unable or unwilling to pay for testing to confirm bacterial infections, it is possible that for veterinarians' broad-spectrum prescription of antimicrobials may be preferred (34). Besides this, if client finances are a factor, cheaper drugs that are inappropriate for the given scenario may be prescribed (35). These considerations are especially important in veterinary medicine, where cost considerations play a role in treatment decisions, especially for clients without pet insurance (35).

Conversely, our survey results indicated that client expectations of receiving antimicrobials did not impact prescription patterns for surveyed veterinarians. For our Likert scale question "Client expectations of receiving antimicrobials influences the way I prescribe," only 25% of small and mixed animal veterinarian responses in the survey agreed with this statement. This is in contrast to previously conducted surveys in other states, where client expectations have been found to play a greater role (19, 20, 36). A study on the influence of

patient's expectations on prescription for acute lower respiratory tract illness found that 85% of patients who expected an antimicrobial prescription received it, and that patients wanting AMPs but not receiving them were more likely to be dissatisfied with their experience, due to reasons such as client compliance, time constraints, communication issues or liability concerns (36). Additionally, when breaking results of our survey's Likert scale question down by species treated, 3 of 5 dairy cattle veterinarians agreed with this statement. Even though this is a small subset of our data, this difference in results amongst types of veterinarians for this question could demonstrate that in animal large animal, there may be more pressure to prescribe antimicrobials than in small or mixed animal veterinary practices. This could be due to a number of factors, including economic considerations of farm or livestock owners who may have strict budgets and expect immediate and cost-effective treatments, or general approach towards productivity in farm settings, where the emphasis is on maintaining herd health and productivity (37, 38).

For the opinion-based question regarding which veterinary antimicrobial guidelines veterinarians refer to in practice, 44% of respondents selected the response "Personally developed antimicrobial use guidelines.". This high proportion of respondents selecting this answer option is notable because this lends to ambiguity on what these guidelines are, how they were developed, and if the personally developed guidelines follow protocols for judicious use of antimicrobials. This result could be connected to the variation seen in treatment plans selected by participants in the scenario-based questions, and additionally demonstrate the importance of continued efforts to promote responsible usage of AMDs, including resources with case specific guidelines and defined treatment protocols. Additionally, when chi square and linear regression analysis were done to investigate any possible associations between answers to this opinion-based question and answering correctly for the scenario-based questions, no statistically significant associations were found. This could indicate that any guidelines followed by veterinarians are not impacting their prescription patterns, or are not useful.

The results of our survey were similar to the results seen in the Colorado CoE surveys, especially for types of antimicrobials prescribed and the impact of client characteristics on prescription patterns. For example, the small animal survey showed that amoxicillin and cefovecin or cephalexin, and amoxicillin-clavulanic acid were commonly prescribed antimicrobials in this type of practice, and the large animal survey showed that tulathromycin and florfenicol were commonly prescribed (19, 20). For the large animal CO survey, results demonstrated that client expectations influenced 40% of veterinarians surveyed, 91% said that producer or owner compliance is a factor that contributes to AMR, and 75% said that client expectations of receiving AMDs impacted prescription patterns (19).

The survey's findings demonstrate the importance of continued efforts to promote responsible use of AMDs in veterinary medicine. Efforts to promote responsible usage of AMDs in veterinary medicine does not just improve the health of animals, but the health of human populations as well (39). Developing a better understanding of these veterinary prescription patterns can help to identify areas for improvement in resources for veterinarians, and work towards reducing the development and spread of antimicrobial resistance in human and animal populations. These continued efforts include improved training through yearly continuing education opportunities, outreach that is intuitive with the veterinary community, financial resources, and the implementation of guidelines and regulations to ensure that AMDs are used judiciously. Resources detailing case definitions for diagnosis and defined treatment protocols could prove particularly helpful in decreasing variability in chosen treatment plans in Washington state. Additionally, adherence to well supported treatment protocols with the narrowest spectrum drugs and the support of diagnostics can help to mitigate the risk for developing resistance that is associated with AMPs, thus improving animal and human health.

Strengths of our study included its continuation of previous veterinary stewardship work done by other states, discreet answer options, and the inclusion of three types of veterinarians in our survey. Our survey includes similar aspects to previous literature, including scenario-

based questions and opinion-based questions, but our survey expands on this by presenting participants with the diagnostic test result through branching logic. Additionally, our use of discreet answer options allowed for smoother data analysis and easier to interpret results. Finally, the inclusion of three types of veterinarians in allowed for easier dissemination of the survey, because types of veterinarians could be recruited as one larger group.

Limitations of our study included uneven demographic sampling that potentially biased our results and small sample size. For example, approximately 50% of all respondents had been in clinical practice for 20 or more years. Studies have suggested that there is an inverse relationship between clinical experience in veterinary practice and knowledge of antimicrobial usage guidelines, and that veterinarians with less years in practice were more aware of antimicrobial stewardship (40, 41, 42). It is possible that due to the age demographics of our respondent population that results were more biased towards antimicrobial prescription across all three types of veterinary practice. Our responses were also primarily from small animal veterinarians, who made up 70% of our total respondent population. Our small sample size limited our statistical power to detect associations between factors that contribute to AMR, factors in AMR prescription, and reference materials consulted and correctness. Future directions of the survey pertain to increased recruitment for the survey and focus groups to expand knowledge of veterinary prescription practice. The survey received 54 complete survey responses that were used for the analysis. The goal of the survey was to solicit a higher response rate, however recruitment online for surveys can be difficult. In person recruitment through professional conferences and additional virtual recruitment through social media could be useful avenues to increase survey responses and continue outreach to Washington state veterinarians. Another potential avenue to increase responses for the survey would be to expand the survey outside of Washington state to other states in the Washington CoE region. This could allow for analysis of regional trends as well, which could lead to interesting insights on interventions for AMR in the CoE outside of Washington State. A potential barrier to this

expansion would be ensuring that current survey questions reflect scenarios encountered in other states in the CoE region. Additionally, focus groups for Washington state veterinarians could be an interesting tool to gain a more descriptive insight into trends seen in the survey, especially in terms of answers to perception and opinion-based questions.

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