Determinants of antimicrobial use practices among veterinary clinicians at The University of Tennessee Veterinary Medical Center

John Eddie Ekakoro [1], **Chika C Okafor** [Corresp. 1]

[1] Department of Biomedical and Diagnostic Sciences, College of Veterinary Medicine at the University of Tennessee, Knoxville, Tennessee, United States

Corresponding Author: Chika C Okafor
Email address: okaforch@utk.edu

Background. Antimicrobial drugs in veterinary medical practice are primarily prescribed for the purposes of maintaining or improving health and increasing productivity. However, their value is being eroded by antimicrobial resistance (AMR). Indiscriminate use of antimicrobial drugs is suggested as one of the modifiable factors contributing to the development of AMR. To reduce indiscriminate use and to improve antimicrobial use, veterinary practices are encouraged to adopt good stewardship practices. Therefore, the objectives of this study were: to identify factors influencing clinician decisions to begin using antimicrobials as well as the choice of antimicrobials used at The University of Tennessee Veterinary Medical Center (UTVMC); to evaluate the practices, perceptions, opinions and concerns of veterinary clinicians at UTVMC concerning antimicrobial use, antimicrobial stewardship, and AMR.

Methods. This study's protocol was approved by the University of Tennessee Knoxville IRB for the Protection of Human Subjects in Research. Survey software was used to send a questionnaire to 121 eligible participants, where all were UTVMC faculty with clinical appointments and house officers. Cumulative logit models were fitted to investigate associations between categorical explanatory variables and ordinal response variables.

Results. A response rate of 51.24% was achieved. Of the 62 respondents, 47 (75.81%) reported that bacteriological culture and antimicrobial susceptibility test results were extremely important in their antimicrobial prescription decision-making. Thirty-two (51.61%) respondents believed antimicrobials are being over-prescribed. The cephalosporin class was the most preferred antimicrobial class, while the lincosamide class was the least preferred. From the multivariable cumulative logit model, year of graduation from veterinary school ($P = 0.034$) and clinicians' primary patient load ($P = 0.009$) were significantly associated with clinicians' degree of concern about AMR.

Conclusions and clinical relevance. The findings suggest a need for more awareness about AMR among veterinary clinicians. Improvements in antimicrobial stewardship are needed, especially among veterinary clinicians who graduated after 1999. Educational practices that target modification of antimicrobial prescription practices of veterinary clinicians would likely improve a Good Stewardship Practice (GSP) mindset. GSP is important in prolonging the efficacy of currently available antimicrobial drugs.

Determinants of antimicrobial use practices among veterinary clinicians at The University of Tennessee Veterinary Medical Center

John Eddie Ekakoro[1]; Chika C. Okafor*[1]

[1]Department of Biomedical and Diagnostic Sciences, College of Veterinary Medicine at the University of Tennessee; 2407 River Drive-Room A201, Knoxville, TN 37996-4542.

*Corresponding author

Chika C. Okafor; okaforch@utk.edu

Abstract

Background. Antimicrobial drugs in veterinary medical practice are primarily prescribed for the purposes of maintaining or improving health and increasing productivity. However, their value is being eroded by antimicrobial resistance (AMR). Indiscriminate use of antimicrobial drugs is suggested as one of the modifiable factors contributing to the development of AMR. To reduce indiscriminate use and to improve antimicrobial use, veterinary practices are encouraged to adopt good stewardship practices. Therefore, the objectives of this study were: to identify factors influencing clinician decisions to begin using antimicrobials as well as the choice of antimicrobials used at The University of Tennessee Veterinary Medical Center (UTVMC); to evaluate the practices, perceptions, opinions and concerns of veterinary clinicians at UTVMC concerning antimicrobial use, antimicrobial stewardship, and AMR.

Methods. This study's protocol was approved by the University of Tennessee Knoxville IRB for the Protection of Human Subjects in Research. Survey software was used to send a questionnaire to 121 eligible participants, where all were UTVMC faculty with clinical appointments and house officers. Cumulative logit models were fitted to investigate associations between categorical explanatory variables and ordinal response variables.

Results. A response rate of 51.24% was achieved. Of the 62 respondents, 47 (75.81%) reported that bacteriological culture and antimicrobial susceptibility test results were extremely important in their antimicrobial prescription decision-making. Thirty-two (51.61%) respondents believed antimicrobials are being over-prescribed. The cephalosporin class was the most preferred antimicrobial class, while the lincosamide class was the least preferred. From the multivariable cumulative logit model, year of graduation from veterinary school ($P = 0.034$) and clinicians'

primary patient load ($P = 0.009$) were significantly associated with clinicians' degree of concern about AMR.

Conclusions and clinical relevance. The findings suggest a need for more awareness about AMR among veterinary clinicians. Improvements in antimicrobial stewardship are needed, especially among veterinary clinicians who graduated after 1999. Educational practices that target modification of antimicrobial prescription practices of veterinary clinicians would likely improve a Good Stewardship Practice (GSP) mindset. GSP is important in prolonging the efficacy of currently available antimicrobial drugs.

Introduction

Antimicrobial drugs in veterinary medical practice are primarily prescribed for the purposes of maintaining or improving health and increasing productivity (Marshall & Levy 2011). However, the emergence and spread of antimicrobial resistant microorganisms is eroding the value of antimicrobial drugs (Dyar et al. 2016; Guardabassi & Prescott 2015). Although antimicrobial resistance (AMR) is an ancient phenomenon (D'costa et al. 2011; Perry et al. 2016), indiscriminate use of antimicrobials has been suggested as one of the modifiable factors contributing to the development of AMR. The increase in the prevalence of microorganisms resistant to antimicrobials is now widely attributed to indiscriminate use, both in veterinary medicine and in human medicine (De Briyne et al. 2013; Holmes et al. 2016).

Recent studies (Marshall & Levy 2011) have shown that indiscriminate use of antimicrobials for both therapeutic and non-therapeutic use in animals leads to propagation and shedding of substantial amounts of antimicrobial resistant microorganisms. It is now widely

known shedding of drug resistant microorganisms by animals leads to human infections through direct contact or indirectly through colonization of humans by commensals, which may carry transferable resistance genes across species through multiple pathways like food, water, airborne particulate matter, and sludge and manure applications to food crop soils (Chung et al. 2017; Marshall & Levy 2011; McEachran et al. 2015; Van Boeckel et al. 2015). Multi-drug resistant infections exert a huge burden on veterinary medical care (Kuzi et al. 2016) and pose public health risks (Walther et al. 2017; Weese et al. 2015). To reduce indiscriminate use and to improve antimicrobial use, veterinary practices are encouraged (Prescott & Boerlin 2016; Weese 2006) to adopt good stewardship practices, such as effective infection control, bacteriologic culture and antimicrobial susceptibility testing, and the use of individual practice guidelines for antimicrobial stewardship.

Research conducted in a veterinary teaching hospital in the U.S. suggests clinicians are frequently prescribing antimicrobials without proper documentation in medical records or without indicating their use (Wayne et al. 2011). Veterinarians in another U.S. veterinary teaching hospital believed antimicrobials were over-prescribed in veterinary practice. The veterinarians in that hospital (Jacob et al. 2015) were concerned about AMR and supported the idea of restricting the use of certain antimicrobial classes in companion animals. Prior to this study, the factors that influenced University of Tennessee Veterinary Medical Center (UTVMC) clinicians to start, delay, or discontinue the use of antimicrobials and/or to determine the class of antimicrobials used were unknown. The perceptions, opinions, and concerns of UTVMC veterinary clinicians in relation to antimicrobial use, antimicrobial stewardship, and AMR were unknown and thus undocumented. Additionally, the association between the effort allocation to

veterinary clinical practice and the frequency of antimicrobial prescriptions for therapeutic treatment of infectious diseases had not been explored.

The objectives of this study were to identify the factors that influence UTVMC clinicians to begin using antimicrobials, to analyze the clinicians' preferential choices of antimicrobials, and to evaluate the perceptions, opinions, and concerns of veterinary clinicians regarding antimicrobial use, antimicrobial stewardship, and AMR. These findings will be beneficial in improving antimicrobial stewardship and educational training on judicious use of antimicrobials. Ultimately, these efforts could prolong the efficacy of current antimicrobials and reduce the burden of AMR within veterinary medicine and public health.

Materials and Methods

Study design and administration of survey

This study's protocol was approved by the University of Tennessee Knoxville Institutional Review Board for the Protection of Human Subjects in Research (UTK IRB-16-02956-XP). The survey questionnaire was developed, and validated by four professionals with expertise in survey research. Next, the survey questionnaire was pre-tested among 4 veterinary clinicians at UTVMC. Comments from the pretest were addressed to improve questionnaire clarity. The survey software (Qualtrics software, January–March 2017, Provo, UT) was set to record responses in progress after each respondent began the survey, allowing respondents to pause and return to the survey as time permitted. The anonymize function in the survey software was optimized, so responses were not attached to any personal identifiers. Adjustments were made to adapt the survey for computer, tablets, and cell phone responses. The updated survey was tested to assess and adjust the functionality of the survey software settings.

The survey had 36 questions programmed to capture the respondent's demographics and their antimicrobial prescription practices, perceptions, opinions, and concerns about antimicrobial use, antimicrobial stewardship, and AMR. Questions regarding demographic information included the nature of their clinical position (faculty versus house officers), the primary type of patients seen (small animal, food animal, equine, etc.), whether they had specialty board certification, where their veterinary degree was obtained (U.S. versus non-U.S.), their total number of years in clinical practice from time of graduation, and their year of graduation from veterinary school. This demographic information was treated as explanatory variables in the analysis. Frequency of antimicrobial prescription and the degree of concern about antimicrobial resistant infections were the main outcomes of interest. Ordinal Likert scales were mostly used to capture participant responses to questions relating to perceptions about antimicrobial use practices.

The email addresses of 121 eligible participants, including all faculty with clinical appointments, residents, and interns at UTVMC, were entered into the survey software. To increase response rate, the eligible participants were notified about the study during departmental meetings a week before the study's start date. Another email reminder was delivered to all 121 potential respondents an hour before the survey invitations were sent.

The invitation to participate contained information about the rationale and objectives of the study. Respondents were required to "accept" or "decline" giving their consent to participate, and no incentive was provided for participation or completion. The survey was designed to be completed in 20 minutes or less, set to accept only one response from each respondent, and remained open for 6 weeks (January 27, 2017 through March 10, 2017). Weekly follow-up email

reminders were sent out to non-respondents, and a thank you message was sent to all respondents at the end of the study.

Statistical analysis

Descriptive and inferential analyses was completed using commercial statistical software (SAS, version 9.4, SAS Institute Inc, Cary, NC). Descriptive statistics (frequencies, proportions, and median) were used to summarize the data. Side-by-side bar charts and stacked bar charts for responses on the three-point scales and on the Likert scales were created using another commercial software (Tableau software, version 8.2, Seattle, WA). Missing data was treated as such. Antimicrobial drugs were ranked from most to least used and were grouped by name into similar classes as described previously (Green et al. 2010; Jacob et al. 2015). The commonly prescribed antimicrobial drugs were grouped into medically important antimicrobial classes as grouped by the United States Food and Drug Administration (FDA 2015).

Spearman's rank correlation (PROC CORR) was used to evaluate for correlations between two ranked variables: for example, the proportion of total professional activity dedicated to clinical practice (effort allocation to clinical practice) and the frequency of prescription of antimicrobials for therapeutic purposes. Cumulative logit models were fitted to assess the association between various predictors and several outcomes. The probabilities modeled were cumulated over the lower ordered values as previously described (Agresti 2006). Number of years in clinical practice (clinical experience) was treated as quantitative by assigning scores to its categories. For categorical explanatory variables, both univariable and multivariable analyses (PROC LOGISTIC) were performed.

Based on the univariable analyses, potential predictors at a $P \leq 0.10$ were considered for inclusion in the multivariable analyses. However, for two predictor variables (number of years in clinical practice from the time of graduation from veterinary school and year of graduation from veterinary school) measuring a similar characteristic, only one variable (year of graduation from veterinary school) was used in the multivariable model building. The multivariable cumulative logit model was fitted using manual backwards elimination with the ordinal response variable—clinicians' degree of concern about AMR—as the outcome. At the multivariable step of model building, statistical significance was assessed at $P = 0.05$.

A high-performance procedure (PROC HPLOGISTIC) was used to investigate the effects of antimicrobial class on clinicians' frequency of prescription and to identify differences in preference between classes of antimicrobials (based on comparisons between classes). During the evaluation, the tetracyclines (eighth class) was set as the reference class. The probability of disliking a class of antimicrobial was modelled.

The score test for the proportional odds assumption, deviance, and Pearson goodness-of-fit statistics were used to assess the model fit. For the high-performance procedure (PROC HPLOGISTIC), a plot of the empirical cumulative logit function was created to test whether the proportional odds assumption held. This plot yielded approximately parallel empirical cumulative logits giving visual evidence that the proportional odds model was appropriate. The 95% confidence intervals were utilized to test significant associations. Values of $P < 0.05$ were considered significant.

Results

Descriptive statistics

Of the 121 invited participants, 62 (51.24%) responded to the survey. A few survey questions were unanswered by some of the participants. The median time taken to complete the survey was 9.82 minutes (range 4.2 – 10,271.47 minutes). The demographic information of the participants is presented in **Table 1**. Among all the factors that influenced the choice of antimicrobial drug(s) for clinical use at UTVMC, results from bacteriological culture and antimicrobial susceptibility tests was the most important influencer. On the other hand, pressure from clients/producers to the clinician to prescribe antimicrobials and fear of litigation by the client/producer in the event of an undesirable clinical outcome were the least important influencers. A detailed description of the factors influencing choice of antimicrobials for clinical use is shown in **Figure 1**.

Regarding the sources UTVMC clinicians rely on to determine their choice of antimicrobial for clinical use, peer-reviewed scientific literature, peer support by clinicians/pharmacist within the hospital, peers within and outside of the hospital, and textbooks/drug handbooks were the most important sources of information on antimicrobial drugs. In contrast, pharmaceutical company representatives, veterinary information network (VIN), and online resources were the least important sources of information for the majority of clinicians. A detailed description of the sources of antimicrobial information the clinicians use to make their choices on antimicrobials for clinical use is shown in **Figure 2**.

Frequency of prescriptions differed among the surveyed clinicians. Twenty respondents (32.26%) reported prescribing antimicrobials for therapeutic purposes more than 5 times a week, while 35 of 62 (56.45%) respondents reported prescribing antimicrobials for prophylactic purposes (**Figure 3**). Of the 35 respondents who reported prescribing antimicrobials for

prophylactic purposes, 23 (65.71%) reported using antimicrobials for pre-operative surgical prophylaxis, 29 (85.29%) reported prescribing antimicrobials for post-operative surgical prophylaxis, and 29 (82.86%) reported using antimicrobials for peri-operative surgical prophylaxis (**Figure 4**).

Clinicians' opinions on antimicrobial use at UTVMC differed. Although 1 respondent (1.61%) thought antimicrobials at UTVMC are prescribed based only on confirmed infections, 21 (33.87%) thought antimicrobials are sometimes prescribed based on no documented evidence of infection, 38 (61.29%) thought that antimicrobials are sometimes prescribed for suspected (but not confirmed) infections, and 2 (3.23%) reported not being sure. One clinician (1.61%) believed that antimicrobials are under-prescribed at UTVMC. Twenty-nine (46.77%) and 32 (51.61%) respondents thought antimicrobials are optimally prescribed and over-prescribed at UTVMC, respectively. In response to whether veterinarians raised on farms prescribed antimicrobials more often than those not raised on farms, 10 (16.13%) respondents agreed, 35 (56.45%) neither disagreed nor agreed, and 17 (27.42%) disagreed.

Overall, 2 (3.23%) respondents believed UTVMC had an antimicrobial stewardship program; 51 (82.26%) respondents were not sure, while 9 (14.52%) thought UTVMC did not have an antimicrobial stewardship program. Within the faculty cohort (n = 44), 8 (13.11%) respondents believed there was no antimicrobial stewardship program at UTVMC, 34 (55.74%) were not sure, and 2 (3.28%) thought that an antimicrobial stewardship program currently exists. However, within the 17 house officers, 1(1.64%) respondent thought no antimicrobial stewardship program existed, and 16 (26.23%) respondents were not sure. The respondent who did not disclose the nature of their clinical position was also not sure of the existence of antimicrobial stewardship program at UTVMC. Of the 9 respondents who reported no

antimicrobial stewardship program currently existing, 2 (22.22%) did not think UTVMC should develop and implement an antimicrobial stewardship program, while 7 (77.78%) thought the opposite.

Regarding the respondents' familiarity with Veterinarian Client Patient Relationship (VCPR), 3 (4.84%) were not familiar at all, 9 (14.52%) were moderately familiar, 17 (27.42%) were very familiar, 33 (53.23%) were extremely familiar. A comparison of the level of familiarity with the VCPR between faculty with clinical appointment and house officers is shown in **Figure 5**. Overall, 10 (16.13%) reported that they never utilize VCPR in their antimicrobial prescription practice, 3 (4.84%) rarely used VCPR, 4 (6.45%) sometimes utilized VCPR), 10 (16.13%) often utilized VCPR, and 35 respondents (56.45%) always utilized VCPR in their antimicrobial prescription practice. A comparison of the use of VCPR in antimicrobial prescription practice of respondents based on the nature of clinical position is shown in **Figure 6**.

For responses to the question about the extent to which their veterinary medical training alone adequately equipped them with knowledge on rational use of antimicrobials, one clinician (1.61%) responded "not at all," 3 (4.84%) responded "a little," 22 (35.48%) responded "somewhat," 28 (45.16%) responded "quite a bit," and 8 (12.9%) responded "very much." One clinician (1.61%) responded that present-day veterinary medical students do not receive any adequate training on rational use of antimicrobials, 9 (14.75%) responded "a little," 28 (45.90%) responded "somewhat," 21 (34.43%) responded "quite a bit," and 2 (3.28%) responded "very much."

Seventeen (27.42%) clinicians have never read the United States Food and Drug Administration (FDA) / American Veterinary Medical Association (AVMA) guidelines for judicious use of antimicrobials, 19 (30.65%) rarely read the guidelines, 20 (32.26%) sometimes

247 do, and 6 (9.68%) very often read the guidelines. In rating other veterinarians' concerns about
248 AMR, 18 clinicians (29.03%) thought other veterinarians were slightly concerned about AMR,
249 36 (58.06%) believed that others were moderately concerned, 5 (8.06%) reported that others
250 were quite concerned, and 3 (4.84%) thought others were very concerned. With respect to their
251 clients' concern about AMR, 27 clinicians (43.55%) thought their clients were not concerned, 25
252 (40.32%) believed they were slightly concerned, 8 (12.9%) thought the clients were moderately
253 concerned, and 2 (3.23%) believed they were quite concerned.

254 Twelve respondents (19.35%) strongly disagreed with the statement "antimicrobial
255 classes commonly used in human medicine should not be used in veterinary medicine because
256 their use in veterinary medicine selects for AMR in microbes affecting humans." Thirty-two
257 (51.61%) disagreed with this statement, 11 (17.74%) neither disagreed nor agreed, and 7
258 (11.29%) agreed with this statement.

259 For the statement "antimicrobial drug use in veterinary practice may lead to AMR in
260 pathogens affecting humans," 1 (1.61%) strongly disagreed, 8 (12.9%) disagreed, 17 (27.42%)
261 neither disagreed nor agreed, 24 (38.71%) agreed, and 12 (19.35%) strongly agreed. One
262 respondent (1.61%) was not concerned about antimicrobial resistant infections. Two (3.23%)
263 were slightly concerned; 27(43.55%) were moderately concerned. Nineteen respondents
264 (30.65%) were quite concerned, and 13 (20.97%) were very concerned about antimicrobial-
265 resistant infections.

266

267 **Univariable analyses**

268 There was a weak positive correlation (r = 0.20211, $P = 0.1152$) between proportion of
269 total professional activity dedicated to clinical practice (effort allocation to clinical practice) and

frequency of prescription of antimicrobials for therapeutic treatment of infectious diseases. Likewise, there was a very weak positive correlation (r = 0.1654, $P = 0.1989$) between period of graduation from veterinary school and frequency of prescription of antimicrobials for therapeutic treatment of infectious diseases.

At this hospital, cephalosporin class was the most preferred antimicrobial class followed by penicillins, while the lincosamides class was least preferred. The tetracycline class was more preferred when compared to the aminoglycosides class. Similarly, the fluoroquinolones, lincosamides, macrolides, and sulfas classes were less favorable than the tetracycline class ($P < 0.05$). The preferential ordering of the medically important antimicrobial classes based on the frequency of prescriptions was as follows: cephalosporins > penicillins > tetracyclines > fluoroquinolones > sulfas > aminoglycosides > macrolides > lincosamides (**Table 2**).

There was a significant association between the number of years in clinical practice (clinical experience) and the degree of concern about antimicrobial resistant infections. The odds of being at a low end of the degree of concern scale decreased as number of years in clinical practice (clinical experience) increased. The estimated odds of the degree of concern about antimicrobial resistant infections being below any given level (instead of above it) multiplied by 0.95 (OR = 0.95; 95% CI, 0.91 to 0.99; $P = 0.018$). Number of years in clinical practice and year of graduation from veterinary school were highly correlated (r = 0.915, $P < 0.001$). Of the two, the year of graduation was included in the multivariable model building because of ease in interpretation.

Results from the univariable analyses for associations between various categorical predictors and clinicians' degree of concern about antimicrobial resistant infections is presented in **Table 3**. No significant association ($P = 0.307$) was found between gender and the degree of

concern for antimicrobial resistant infections. For male clinicians, the estimated odds that the response was below any particular level of concern (instead of above it) were 1.01 times the estimated odds for female clinicians. A significant association ($P = 0.043$) was found between the nature of clinical position and the degree of concern about AMR. For house officers, the estimated odds that the response was below any particular level of concern were 3.19 times the estimated odds for faculty with clinical appointments. House officers were more likely to be less concerned when compared to faculty with clinical appointments.

Year of graduation from veterinary school was significantly associated ($P = 0.040$) with the degree of concern about antimicrobial resistant infections. For clinicians who graduated from 2000–2009, the estimated odds that the response was below any particular level of concern were 2.83 times the estimated odds for those who graduated from 1970–1999. For clinicians who graduated from 2010–2016, the estimated odds that the response was below any particular level of concern were 4.55 times the estimated odds for those who graduated from 1970–1999. Clinicians who graduated after 1999 tended to be less concerned about AMR when compared to those who graduated from 1970–1999.

Where veterinary degree was obtained was not significantly associated ($P = 0.343$) with the degree of concern about antimicrobial resistant infections. However, for participants who obtained their veterinary degree from a US veterinary school, the estimated odds that the response was below any particular level of concern were 1.788 times the estimated odds for those who obtained their veterinary degree from outside the US. Specialty board certification was not significantly associated ($P = 0.054$) with the degree of concern about antimicrobial resistant infections. For participants without specialty board certification, the estimated odds that

the response was below any particular level of concern were 2.84 times the estimated odds for those with board certification.

Primary patient load was not significantly associated ($P = 0.067$) with the degree of concern about antimicrobial resistant infections. For participants whose primary patient load involved other animal species (equine, food animal, mixed animal, exotics, all large-equine, and food animal), the estimated odds that the response was below any particular level of concern were 2.47 times the estimated odds for small animal clinicians. Participants whose primary patient load involved other animal species were more likely to be less concerned about antimicrobial resistant infections when compared to small animal clinicians.

Multivariable analyses

From the univariable models, four predictors—the nature of clinical position ($P = 0.043$), year of graduation from veterinary school ($P = 0.040$), specialty board certification ($P = 0.054$), and primary patient load ($P = 0.067$)—were included in the multivariable model using a liberal value of $P \leq 0.10$ as the cut-off point. In the multivariable cumulative logit model, only two predictors, year of graduation from veterinary school ($P = 0.034$) and clinicians' primary patient load ($P = 0.009$) were found to be significantly associated with clinicians' degree of concern about antimicrobial resistant infections. For clinicians who obtained their veterinary degree from 2010 to 2016, the estimated odds that the response was below any particular level of concern about AMR (instead of above it) were 5.09 times the estimated odds for clinicians who graduated between 1970 to 1999 (OR for 2010–2016 vs 1970–1999, 5.09; 95% CI, 1.46 to 17.72; $P = 0.011$). In other words, controlling for primary patient load, clinicians who graduated from 2010

to 2016 tended to be less concerned about AMR when compared to those who graduated from 1970 to 1999.

Although not significantly different, the estimated odds that the response was below any particular level of concern about AMR (instead of above it) for clinicians who obtained their veterinary degree from 2000–2009 were 2.77 times the estimated odds for clinicians who graduated from 1970–1999 (OR for 2000–2009 vs 1970–1999, 2.77; 95% CI, 0.88 to 8.68; $P = 0.080$). Similarly (although not significantly different), the estimated odds that the response was below any particular level of concern about AMR (instead of above it) for clinicians who obtained their veterinary degree from 2010–2016 were 1.84 times the estimated odds for clinicians who graduated from 2000–2009 (OR for 2010–2016 vs 2000–2009, 1.84; 95% CI, 0.57 to 5.95; $P = 0.311$).

For participants whose primary patient load involved other animal species (equine, food animal, mixed animal, exotics, all large—equine, and food animal), the estimated odds that the response was below any particular level of concern about AMR (instead of above it) were 3.98 times the estimated odds for small animal clinicians (OR for others vs small animal, 3.98; 95% CI, 1.42 to 11.16; $P = 0.009$). In other words, controlling for year of graduation from veterinary school, clinicians whose primary patient load involved other animal species tended to be less concerned about antimicrobial resistant infections when compared to small animal clinicians.

Discussion

This study was designed to identify the factors influencing clinicians to begin an antimicrobial regimen, the process of choosing the antimicrobials used at UTVMC, and evaluate

359 the perceptions, opinions, and concerns of veterinary clinicians at UTVMC about antimicrobial
360 use, antimicrobial stewardship, and AMR. In this study, we identified several factors that
361 influence clinician decisions to prescribe antimicrobial agents. Our results have shown the
362 relationships between demographic characteristics of veterinary clinicians and the clinicians'
363 degree of concern about AMR at a veterinary teaching hospital in the United States.
364 Additionally, we have shown the preferential ordering of medically important classes of
365 antimicrobial drugs based on UTVMC veterinary clinicians' self-reported frequency of
366 prescription.

367 For this survey, we achieved a response rate of 51.24%. This response rate was high
368 when compared to other surveys among veterinarians in the US and elsewhere (Chipangura et al.
369 2017; Fowler et al. 2016; Grayzel et al. 2015; Jacob et al. 2015; Postma et al. 2016). The high
370 response rate achieved in this study may have resulted from the efforts employed to increase the
371 response rate, including attending departmental and weekly clinical rounds meetings before the
372 survey was sent and sending out weekly email reminders to participants. A previous study
373 (Postma et al. 2016) suggested that communicating the importance of the survey along with
374 sending reminders to respondents through diverse media could improve response rates.

375 In the present study, 47 respondents (75.81%) reported results from bacteriological
376 culture and susceptibility tests to be an extremely important factor in deciding the choice of
377 antimicrobial to use. This is consistent with the findings of other studies, (De Briyne et al. 2013;
378 Jacob et al. 2015) where veterinarians rated bacteriologic culture and antimicrobial susceptibility
379 among the most important factors in clinical decision making. We believe this is a very
380 important finding given that use of bacteriological culture and antimicrobial susceptibility test
381 results, along with other Good Stewardship Practices (GSP), is very important in the practice of

evidence-based antimicrobial therapy (Guardabassi & Prescott 2015; Prescott & Boerlin 2016; Rubin 2013). Pressure from clients/producers to the clinician to prescribe antimicrobials was scored "not at all important" by 45.16% of the respondents and "slightly important" by 40.32% of the respondents. Likewise, fear of litigation by the client/producer was not an important factor. These findings suggest that power distance, (Hulscher et al. 2010) the hierarchical distance between the veterinary clinician and client/producer in the UTVMC clinical setting, is narrow, and uncertainty avoidance may not be a very influential factor in prescription decision making in the UTVMC clinical setting. Culture and societal norms are known to influence antimicrobial prescribing practices (Cheng & Worth 2015) with cultural measures of uncertainty avoidance and wide power distance between the clinician and client/producer influencing prescription practices. Clinicians with high uncertainty avoidance would be more likely to prescribe antimicrobials in the event of undesirable clinical outcomes.

The sources of antimicrobial information that clinicians utilize in determining their choice of antimicrobial for clinical use at UTVMC are similar to those identified in other studies in the US and elsewhere (De Briyne et al. 2013; Hardefeldt et al. 2017; Hughes et al. 2012; Jacob et al. 2015; Knights et al. 2012; Postma et al. 2016). Peer-reviewed literature was ranked as "extremely important" by 35 of 62 (56.45%) respondents, while pharmaceutical company representatives were ranked "not at all important" by 34 of 62 (54.84%) respondents. A previous study (Hughes et al. 2012) reported that 70% of their respondents ranked pharmaceutical companies as an important source of information on antimicrobial drugs.

In routine surgical practice, antimicrobial drugs may appropriately be used pre-operatively, peri-operatively, or post-operatively for prophylaxis against surgical site infections, often based on the judgement of the surgeon. Appropriate use of antimicrobials for surgical

prophylaxis is especially important when surgeries are performed either in suboptimal conditions, such as in farm animal practice, (Dumas et al. 2016) or when the surgical procedure is classified as contaminated (Boothe & Boothe 2015). In the present study, 35 of 62 (56.45%) reported that they prescribe antimicrobials for prophylactic purposes. Of the 35 respondents who reported prescribing antimicrobials for prophylactic purposes, 23 (65.71%) reported that they use antimicrobials for pre-operative surgical prophylaxis, 29 (82.86%) reported that they use antimicrobials for peri-operative surgical prophylaxis, and 29 (85.29%) reported that they prescribe antimicrobials for post-operative surgical prophylaxis. These results show that at this hospital, antimicrobials are used for surgical prophylaxis by a large segment of clinicians. In addition, only a few respondents (14.75%) reported that they prescribe antimicrobials for metaphylaxis, while the majority reported that they never prescribe antimicrobials for metaphylaxis. This suggests that prescription of antimicrobials for metaphylaxis at this hospital is occasional and perhaps only in exceptional situations.

In this study, 21 respondents (33.87%) thought that antimicrobials are sometimes prescribed based on no documented evidence of infection, while 38 (61.29%) thought that antimicrobials are sometimes prescribed for suspected (but not confirmed) infections. A recent retrospective study (Wayne et al. 2011) from a veterinary school showed similar findings: 38% of antimicrobial prescription did not have documented evidence of infection, while 45% of antimicrobial prescriptions at that hospital were for suspected infections. In our study, 32 respondents (51.61%) believed that antimicrobials are over-prescribed. Clinicians in another US teaching hospital (Jacob et al. 2015) also held a similar view that antimicrobials were overprescribed.

In the present study, only 2 (3.23%) respondents reported that UTVMC has an antimicrobial stewardship program, 51 (82.26%) of respondents reported they are "not sure" whether UTVMC has an antimicrobial stewardship program, and 9 (14.52%) reported that UTVMC did not have an antimicrobial stewardship program. In reality, there was no antimicrobial stewardship program being implemented at this hospital at the time the present survey was conducted. Clinicians were trusted and expected to make sound judgement on judicious use of antimicrobials based on their veterinary training. These findings suggested a need to develop and implement an antimicrobial stewardship program at this hospital. Additionally, the disparities in these opinions might be due to variations in knowledge and awareness among respondents about what constitutes an antimicrobial stewardship program, suggesting a need for more training and awareness on antimicrobial stewardship and GSP. Antimicrobial stewardship programs involve multifaceted approaches that aim to sustain the efficacy of antimicrobial drugs, while minimizing the emergence of AMR (Prescott & Boerlin 2016). Some of the respondents in this survey reported that they were not at all familiar with VCPR. It might be possible that respondents who reported that they were not at all familiar with VCPR had clinical duties that did not directly involve antimicrobial prescription. Some respondents stated that their clinical duties did not directly involve prescription of antimicrobials. Other respondents reported that they never utilize VCPR in their antimicrobial prescribing practice. This might be because utilization of VCPR in a tertiary care veterinary teaching hospital like UTVMC may be impractical in certain clinical situations because some patients from referring veterinarians may be admitted for emergency veterinary care and not be involved in VCPR.

To promote judicious use of antimicrobials, some regulatory bodies and veterinary professional organizations have developed guidelines for judicious antimicrobials by veterinary clinicians. A previous study suggested that compliance with antimicrobial use guidelines may have led to a reduction in overall antimicrobial use at a veterinary teaching hospital (Weese 2006). However, in the present study, seventeen (27.42%) clinicians never read FDA/AVMA guidelines for judicious use of antimicrobials, 19 (30.65%) rarely read the guidelines, 20 (32.26%) sometimes read, and 6 (9.68%) very often read the FDA/AVMA guidelines. These findings suggest a generally low uptake of antimicrobial use guidelines among the respondents of this survey. It is possible that there is little awareness among the respondents about the existing guidelines for judicious use of antimicrobials. A previous survey (Grayzel et al. 2015) found that 218 of 247 (88%) respondents were unaware of the available guidelines for judicious use of antimicrobials. There is need for more awareness about and compliance with the available antimicrobial use guidelines among veterinary clinicians.

A previous study (Gjelstad et al. 2011) suggested that antimicrobial prescribing may be a time-saving strategy for some busy physicians. At the design of this present study, we had hypothesized that busy veterinary clinicians with less effort allocation to clinical practice and more effort allocation to other non-clinical duties would perhaps play safe by prescribing broad-spectrum antimicrobials as a timesaving strategy in the face of diagnostic uncertainties. However, our findings showed that effort allocation to clinical practice was not significantly correlated with frequency of prescription of antimicrobials for therapeutic treatment of infectious diseases at UTVMC.

Our study provides evidence of the preference ordering of medically important antimicrobial classes at UTVMC. At this hospital, cephalosporins were the most preferred class

472 followed by the penicillins. Recent studies of veterinary antimicrobial prescribing practices in
473 the US also showed similar findings, with β-lactams being the most commonly prescribed drug
474 class (Baker et al. 2012; Fowler et al. 2016). Our findings suggest the need for antimicrobial
475 stewardship strategies, such as de-escalation and antimicrobial cycling, to minimize likely
476 buildup of AMR to the most preferred classes at this hospital.

477 In this study, experience of the veterinary clinician, measured as number of years in
478 clinical practice, had a significant effect ($P < 0.05$) on the degree of concern about antimicrobial
479 resistant infections, suggesting that clinicians with more clinical experience tended to be more
480 concerned about antimicrobial resistant infections. We consider this a novel finding. Arguably,
481 this study demonstrates for the first time that the experience of the veterinary clinician, measured
482 as number of years in clinical practice, is significantly associated with clinician's degree of
483 concern about antimicrobial resistant infections.

484 In the multivariable cumulative logit model, we have shown that year of graduation from
485 veterinary school ($P = 0.034$) and clinicians' primary patient load ($P = 0.009$) were significantly
486 associated with clinicians' degree of concern about AMR. Moreover, for clinicians who obtained
487 their veterinary degree from 2010-2016, the estimated odds that the response was below any
488 particular level of concern about AMR (instead of above it) were 5.09 times the estimated odds
489 for clinicians who graduated from 1970-1999. Clinicians who graduated after 1999 generally
490 tended to be less concerned about AMR than those who graduated from 1970-1999. There are
491 two possible explanations for this finding. First, it could be that clinicians who graduated from
492 1970-1999 are more experienced and have received greater exposure and awareness about the
493 risks associated with antimicrobial resistant infections when compared to those who graduated
494 after 1999. Second, it is possible that this finding reflects an inadequate emphasis on the

judicious use of antimicrobial drugs in the teaching of veterinary pharmacology and therapeutics in veterinary schools over the recent years. The opinion of other researchers is that the teaching of AMR and antimicrobial pharmacology in most veterinary schools is inadequate. In the present study, one clinician (1.61%) responded that present day veterinary medical students do not at all receive adequate training on rational use of antimicrobials, 9 (14.75%) responded "a little," 28 (45.90%) responded "somewhat," 21 (34.43%) responded "quite a bit," and 2 (3.28%) responded "very much." Similarly, clinicians whose primary patient load involved other animal species tended to be less concerned about antimicrobial resistant infections when compared to small animal clinicians. This finding may reflect perhaps greater access by small animal clinicians to continued professional development related to rational antimicrobial use. The differences in clinicians' degree of concern about AMR by year of graduation from veterinary school and by clinicians' primary patient load needs to be further investigated in other veterinary teaching hospitals. It would be interesting to evaluate the associations between year of graduation from veterinary school, primary patient load, and clinicians' degree of concern about AMR in other tertiary veterinary teaching hospitals as well as in primary care veterinary hospitals. Educational interventions, such as an increased educational emphasis about antimicrobial stewardship approaches for veterinary students and continuing professional development for practicing veterinarians aimed at promoting prudent antimicrobial use by veterinary clinicians at all levels of clinical experience, may be helpful in modifying prescription behaviors and practices of clinicians. Good education of antimicrobial prescribers has been suggested as a potent approach to reduction of non-judicious antimicrobial use through improved understanding and acceptance of antimicrobial stewardship (Guardabassi & Prescott 2015).

The main limitation of our study is the relatively few respondents (n = 62). It is also possible there was a flaw in survey design that could have affected how the respondents interpreted the survey questions. Similarly, fewer house officers (n = 17) responded to the survey when compared to faculty with clinical appointments (n = 44), despite a response rate of 51.24%. The response rate could not be increased beyond 51.24%. However, there was greater variation in respondents in terms of gender, number of years in clinical practice, and specialty board certification. Response bias (social desirability bias) and non-response bias, could have impacted the validity of this study. It is possible that the survey answers of the respondents could have differed from the answers of non-respondents. Non-responder analysis was not possible because it would breach the confidentiality and anonymity of the responses. Despite the above limitations, the results of this study provide useful information that is vital for improvements in antimicrobial stewardship.

Conclusions

For many clinicians at this hospital, bacteriological culture and susceptibility tests were an extremely important factor influencing the choice of antimicrobial agents, while peer-reviewed literature and peers (other veterinarians) were very important sources of antimicrobial information. This study revealed that at the time when this study was conducted, cephalosporin class was the most preferred class of antimicrobials, while the lincosamide class was the least preferred at this hospital. Furthermore, clinicians' degree of concern about AMR differed by year of graduation from veterinary school and clinicians' primary patient load, with clinicians who graduated after 1999 generally tending to be less concerned about AMR than those who

graduated from 1970-1999. Clinicians whose primary patient load involved other animal species tended to be less concerned about antimicrobial resistant infections when compared to small animal clinicians. There is need for more awareness about AMR and about guidelines for judicious use of antimicrobials among veterinary clinicians. Improvements in antimicrobial stewardship are needed, especially among clinicians who graduated after 1999. The findings of this study should be helpful in improving antimicrobial stewardship and educational practices on judicious use of antimicrobials in veterinary teaching hospitals. This, in the long run could lead to a modification of prescription practices of veterinary clinicians, thus contributing to the reduction of the AMR burden in veterinary medicine and public health.

Acknowledgements

The authors thank Ms. Cary Springer, Drs. Nancy Howell, J. Mark Fly, and Agricola Odoi for technical assistance. No third-party funding was received in connection with this study or the writing or publication of this manuscript.

References

Agresti A. 2006. Multicategory Logit Models. *An Introduction to Categorical Data Analysis*. 2nd ed: John Wiley & Sons, Inc., 173-203.

Baker SA, Van-Balen J, Lu B, Hillier A, and Hoet AE. 2012. Antimicrobial drug use in dogs prior to admission to a veterinary teaching hospital. *Journal of the American Veterinary Medical Association* 241:210-217.

Boothe DM, and Boothe HW. 2015. Antimicrobial Considerations in the Perioperative Patient. *Veterinary Clinics of North America: Small Animal Practice* 45:585-608. http://dx.doi.org/10.1016/j.cvsm.2015.01.006

Cheng AC, and Worth LJ. 2015. Cultural dimensions relevant to antimicrobial stewardship: the contribution of individualism and power distance to perioperative prescribing practices in European hospitals. *Healthcare infection* 20:124-127.

Chipangura JK, Eagar H, Kgoete M, Abernethy D, and Naidoo V. 2017. An investigation of antimicrobial usage patterns by small animal veterinarians in South Africa. *Preventative Veterinary Medicine* 136:29-38. http://dx.doi.org/10.1016/j.prevetmed.2016.11.017

Chung YS, Hu YS, Shin S, Lim SK, Yang SJ, Park YH, and Park KT. 2017. Mechanisms of quinolone resistance in Escherichia coli isolated from companion animals, pet-owners, and non-pet-owners. *Journal of Veterinary Science*.

D'costa VM, King CE, Kalan L, Morar M, Sung WW, Schwarz C, Froese D, Zazula G, Calmels F, and Debruyne R. 2011. Antibiotic resistance is ancient. *Nature* 477:457.

De Briyne N, Atkinson J, Pokludova L, Borriello SP, and Price S. 2013. Factors influencing antibiotic prescribing habits and use of sensitivity testing amongst veterinarians in Europe. *Veterinary Record* 173:475. 10.1136/vr.101454

Dumas SE, French HM, Lavergne SN, Ramirez CR, Brown LJ, Bromfield CR, Garrett EF, French DD, and Aldridge BM. 2016. Judicious use of prophylactic antimicrobials to reduce abdominal surgical site infections in periparturient cows: part 1 – a risk factor review. *Veterinary Record* 178:654.

581 Dyar OJ, Obua C, Chandy S, Xiao Y, Stalsby Lundborg C, and Pulcini C. 2016. Using
582 antibiotics responsibly: are we there yet? *Future Microbiology* 11:1057-1071.
583 10.2217/fmb-2016-0041
584 FDA. 2015. *2013 Summary Report on Antimicrobials Sold or Distributed for Use in Food-*
585 *Producing Animals (April, 2015)*. Available at
586 https://www.fda.gov/downloads/ForIndustry/UserFees/AnimalDrugUserFeeActADUFA/
587 UCM440584.pdf.
588 Fowler H, Davis M, Perkins A, Trufan S, Joy C, Buswell M, McElwain T, Moore D, Worhle R,
589 and Rabinowitz P. 2016. A survey of veterinary antimicrobial prescribing practices,
590 Washington State 2015. *Veterinary Record* 179:651-651.
591 Gjelstad S, Straand J, Dalen I, Fetveit A, Strøm H, and Lindbæk M. 2011. Do general
592 practitioners' consultation rates influence their prescribing patterns of antibiotics for
593 acute respiratory tract infections? *Journal of antimicrobial chemotherapy* 66:2425-2433.
594 Grayzel SE, Bender JB, Glore RP, Gumley N, Sykes JE, Whichard JM, Papich MG, Watts JL,
595 Barlam TF, and Murphy MJ. 2015. Understanding companion animal practitioners'
596 attitudes toward antimicrobial stewardship. *Journal of the American Veterinary Medical*
597 *Association* 247:883-884.
598 Green AL, Carpenter LR, Edmisson DE, Lane CD, Welborn MG, Hopkins FM, Bemis DA, and
599 Dunn JR. 2010. Producer attitudes and practices related to antimicrobial use in beef cattle
600 in Tennessee. *Journal of the American Veterinary Medical Association* 237:1292-1298.
601 Guardabassi L, and Prescott JF. 2015. Antimicrobial Stewardship in Small Animal Veterinary
602 Practice. *Veterinary Clinics of North America: Small Animal Practice* 45:361-376.
603 http://dx.doi.org/10.1016/j.cvsm.2014.11.005

Hardefeldt LY, Browning GF, Thursky K, Gilkerson JR, Billman-Jacobe H, Stevenson MA, and Bailey KE. 2017. Antimicrobials used for surgical prophylaxis by companion animal veterinarians in Australia. *Veterinary Microbiology* 203:301-307. http://dx.doi.org/10.1016/j.vetmic.2017.03.027

Holmes AH, Moore LS, Sundsfjord A, Steinbakk M, Regmi S, Karkey A, Guerin PJ, and Piddock LJ. 2016. Understanding the mechanisms and drivers of antimicrobial resistance. *The Lancet* 387:176-187. 10.1016/s0140-6736(15)00473-0

Hughes LA, Williams N, Clegg P, Callaby R, Nuttall T, Coyne K, Pinchbeck G, and Dawson S. 2012. Cross-sectional survey of antimicrobial prescribing patterns in UK small animal veterinary practice. *Preventive Veterinary Medicine* 104:309-316.

Hulscher ME, van der Meer JW, and Grol RP. 2010. Antibiotic use: how to improve it? *International Journal of Medical Microbiology* 300:351-356. 10.1016/j.ijmm.2010.04.003

Jacob ME, Hoppin JA, Steers N, Davis JL, Davidson G, Hansen B, Lunn KF, Murphy KM, and Papich MG. 2015. Opinions of clinical veterinarians at a US veterinary teaching hospital regarding antimicrobial use and antimicrobial-resistant infections. *Journal of the American Veterinary Medical Association* 247:938-944. 10.2460/javma.247.8.938

Knights C, Mateus A, and Baines S. 2012. Current British veterinary attitudes to the use of perioperative antimicrobials in small animal surgery. *Veterinary Record* 170:646-646.

Kuzi S, Blum S, Kahane N, Adler A, Hussein O, Segev G, and Aroch I. 2016. Multi-drug-resistant Acinetobacter calcoaceticus-Acinetobacter baumannii complex infection outbreak in dogs and cats in a veterinary hospital. *Journal of Small Animal Practice* 57:617-625.

627 Marshall BM, and Levy SB. 2011. Food animals and antimicrobials: impacts on human health.
628 *Clinical Microbiology Reviews* 24:718-733. 10.1128/cmr.00002-11
629 McEachran AD, Blackwell BR, Hanson JD, Wooten KJ, Mayer GD, Cox SB, and Smith PN.
630 2015. Antibiotics, bacteria, and antibiotic resistance genes: aerial transport from cattle
631 feed yards via particulate matter. *Environmental health perspectives* 123:337.
632 Perry J, Waglechner N, and Wright G. 2016. The Prehistory of Antibiotic Resistance. *Cold*
633 *Spring Harbor Perspectives in Medicine* 6. 10.1101/cshperspect.a025197
634 Postma M, Speksnijder DC, Jaarsma AD, Verheij TJ, Wagenaar JA, and Dewulf J. 2016.
635 Opinions of veterinarians on antimicrobial use in farm animals in Flanders and the
636 Netherlands. *Veterinary Record* 179:68. 10.1136/vr.103618
637 Prescott JF, and Boerlin P. 2016. Antimicrobial use in companion animals and Good
638 Stewardship Practice. *Veterinary Record* 179:486-488.
639 Rubin JE. 2013. Antimicrobial susceptibility testing methods and interpretation of results. In:
640 Giguère S, Prescott JF, eds. *Antimicrobial Therapy in Veterinary Medicine,* Fifth
641 Edition:11-20.
642 Van Boeckel TP, Brower C, Gilbert M, Grenfell BT, Levin SA, Robinson TP, Teillant A, and
643 Laxminarayan R. 2015. Global trends in antimicrobial use in food animals. *Proceedings*
644 *of the National Academy of Sciences of the United States of America* 112:5649-5654.
645 Walther B, Tedin K, and Lübke-Becker A. 2017. Multidrug-resistant opportunistic pathogens
646 challenging veterinary infection control. *Veterinary Microbiology* 200:71-78.
647 http://dx.doi.org/10.1016/j.vetmic.2016.05.017

Wayne A, McCarthy R, and Lindenmayer J. 2011. Therapeutic antibiotic use patterns in dogs: observations from a veterinary teaching hospital. *Journal of Small Animal Practice* 52:310-318.

Weese JS. 2006. Investigation of antimicrobial use and the impact of antimicrobial use guidelines in a small animal veterinary teaching hospital: 1995–2004. *Journal of the American Veterinary Medical Association* 228:553-558.

Weese JS, Giguère S, Guardabassi L, Morley PS, Papich M, Ricciuto DR, and Sykes JE. 2015. ACVIM Consensus Statement on Therapeutic Antimicrobial Use in Animals and Antimicrobial Resistance. *Journal of Veterinary Internal Medicine* 29:487-498. 10.1111/jvim.12562

671

672

673

Figure 1

Factors that influence antimicrobial use at The University of Tennessee Veterinary Medical center

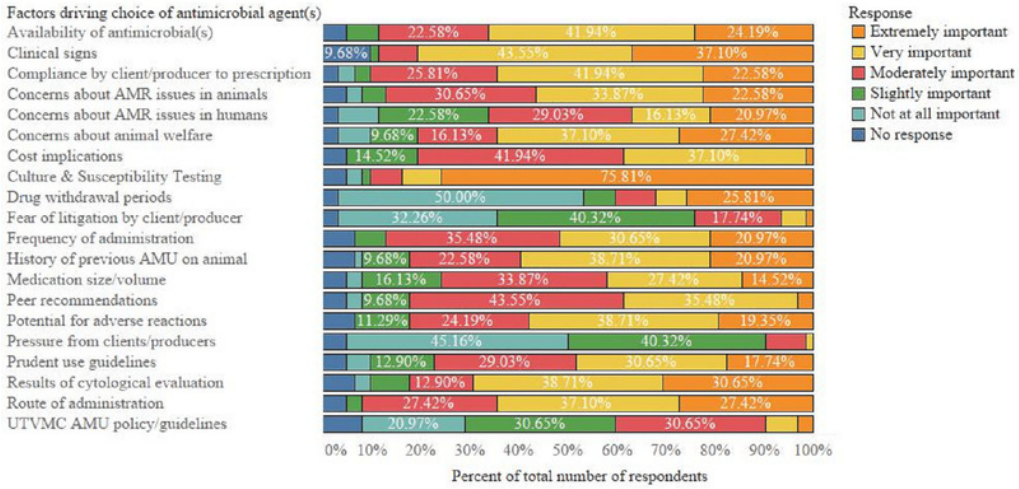

Figure 2

Distribution of sources of antimicrobial information that clinicians utilize in determining their choice of antimicrobial for clinical use at UTVMC

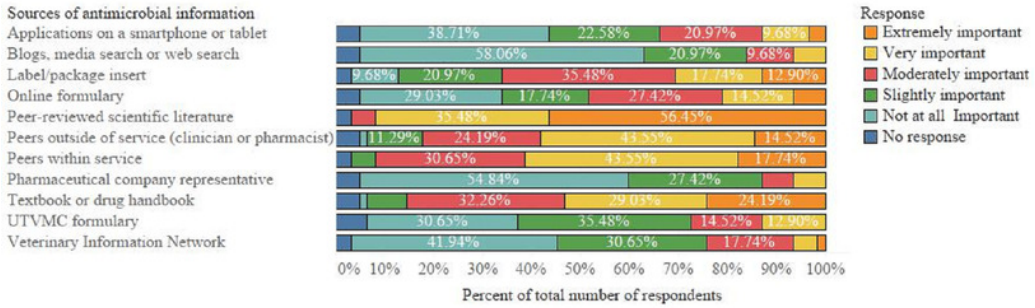

Figure 3

Self-reported antimicrobial prescription practices of veterinary clinicians at UTVMC, 2017

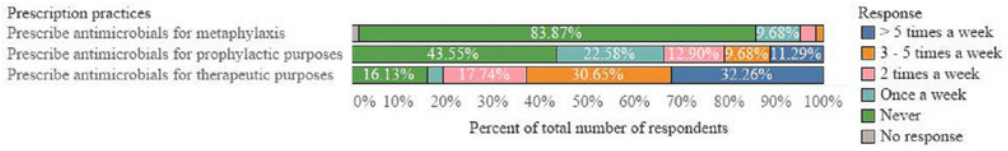

Figure 4

Self-reported antimicrobial prescription practices for surgical prophylaxis by veterinary clinicians at UTVMC, 2017

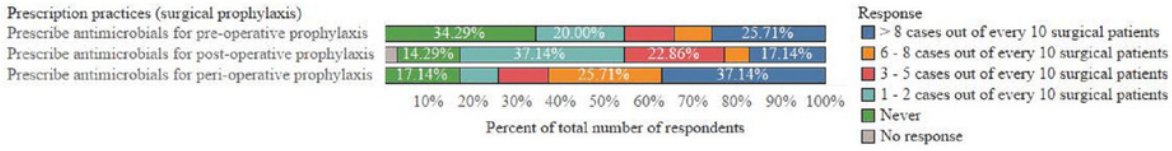

Figure 5

Clinicians' self-reported level of familiarity with VCPR at UTVMC, 2017.

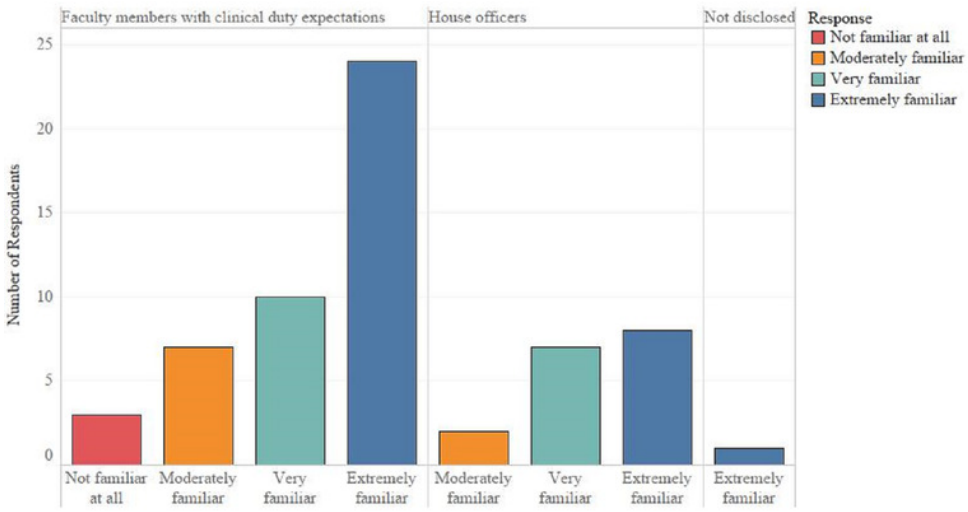

Figure 6

Self-reported use of VCPR in antimicrobial prescription practice by veterinary clinicians at UTVMC, 2017.

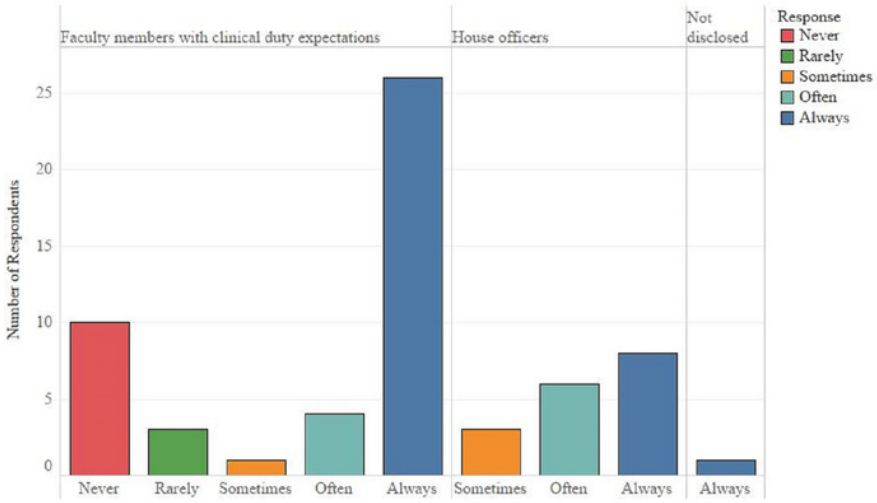

Table 1(on next page)

Demographics of participants on an online survey to identify determinants of antimicrobial use practices among veterinary clinicians at UTVMC, 2017

1

Variable	Number (%) of respondents
Gender	
Female	37 (59.68)
Male	21 (33.87)
Preferred not to report gender	4 (6.45)
Nature Clinical Position	
Faculty member with clinical duty expectations	44 (71)
House officers	17 (27.4)
Not reported	1 (1.6)
Year of graduation from veterinary school	
1970 - 1999	21 (33.87)
2000 - 2009	22 (35.48)
2010 - 2016	19 (30.65)
College where veterinary degree was obtained	
U.S veterinary school	51 (82.26)
Non-U.S veterinary school	11 (17.74)
Primary patient load	
Small animal	37 (59.68)
Equine	8 (12.9)
Food animal	7 (11.29)
Mixed animal	4 (6.45)
Exotic	5 (8.06)
All large: equine and food animal	1 (1.61)
Specialty board certification	
Obtained specialty board certification	43 (69.4)
No specialty board certification	19 (30.64)

2

3

4

5

6

7

Table 2(on next page)

Results showing the preference ordering (from most preferred to least preferred) of medically important antimicrobial classes based on clinicians' self-reported frequency of prescription at UTVMC.

1

Antimicrobial class	Parameter estimate	Standard error	Odds ratio (95% CI)	*P* value
Cephalosporins (most preferred class)	–0.4027	0.3410	0.67 (0.34 – 1.30)	0.238
Penicillins	–0.2669	0.3524	0.77 (0.38 – 1.53)	0.449
Tetracyclines (reference class)	—	—	—	—
Fluoroquinolones	0.5596	0.3374	1.75 (0.90 – 3.39)	0.097
Sulfas	1.0817	0.3422	2.95 (1.51 – 5.77)	0.002
Aminoglycosides	2.1030	0.3513	8.19 (4.11 – 16.31)	<0.001
Macrolides	1.6893	0.3442	5.42 (2.76 – 10.63)	<0.001
Lincosamides (least preferred class)	2.8381	0.3585	17.08 (8.46 – 34.49)	<0.001

2

3

Table 3(on next page)

Univariable analyses for associations between various demographic predictors and clinicians' degree of concern about antimicrobial resistant infections at UTVMC, 2017

1

2

Variable	Category	OR (95% CI)	*P* Value
Gender	Male vs Female	1.01 (0.37 – 2.74)	0.307
Nature of clinical position	House officers vs Faculty with clinical appointment	3.19 (1.04 – 9.79)	0.043
Year of graduation from veterinary school	2000 – 2009 vs 1970 – 1999	2.83 (0.91 – 8.77)	0.071
	2010 – 2016 vs 1970 – 1999	4.55 (1.35 – 15. 38)	0.015
	2010 – 2016 vs 2000 – 2009	1.61 (0.49 – 5.25)	0.431
Where Veterinary Degree was obtained	US vs Non-US	1.79 (0.54 – 5.94)	0.343
Specialty board certification	No vs Yes	2.84 (0.98 – 8.19)	0.054
Primary patient load	Others* vs Small animal	2.47 (0.94 – 6.52)	0.067

*Others was a cluster that was formed out of 5 categories: equine, food animal, mixed animal, exotics, all large (equine and food animal).

3

4