Viewpoint

# The role of companion animal veterinarians in one-health efforts to combat antimicrobial resistance

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Antimicrobial resistance is a growing challenge facing people and animals globally, and antimicrobial-resistant organisms have been found in people, animals, and the environment (eg, water, soil, and air).[1] The CDC estimates that antimicrobial-resistant bacterial infections sicken at least 2 million people and directly cause at least 23,000 deaths annually in the United States.[1] Because these organisms are capable of spreading from person to person, bidirectionally between animals and people, and by way of food, water, and other environmental vehicles, preserving the effectiveness and availability of antimicrobial drugs demands systems-level thinking and the engagement of stakeholders across the human, animal, and environmental health fields in a one-health approach. The AVMA has defined one health as "the integrative effort of multiple disciplines working locally, nationally, and globally to attain optimal health for people, animals, and the environment,"[2] and it follows that it is only through the contributions of and collaborations among the many involved stakeholders that a problem as complex and widespread as antimicrobial resistance can be addressed.

Companion animal veterinarians face increasing numbers of antimicrobial-resistant bacterial infections in their patients. The most common of these infections involve resistant strains of *Escherichia coli* and methicillin-resistant strains of *Staphylococcus pseudintermedius*, but infections with methicillin-resistant strains of *Staphylococcus aureus* and resistant strains of *Enterococcus* spp, *Klebsiella* spp, *Proteus* spp, and *Pseudomonas aeruginosa* have also been documented.[3–5] These antimicrobial-resistant infections can be difficult to treat because the medications used are typically more costly and result in more adverse effects than medications used to treat infections caused by susceptible bacteria **(Table 1)**, and treatment may result in worse outcomes, raising animal welfare concerns.[3,4,6] Treatment of antimicrobial-resistant infections can also be more costly because of the need for multiple recheck visits, repeated bacterial culture and susceptibility testing, and monitoring for adverse effects.[5,7] For example, in a study[8] involving 216 dogs undergoing treatment for pyoderma, 33% of dogs with infections caused by methicillin-resistant *S pseudintermedius* had adverse effects, compared with < 6% of dogs with infections caused by methicillin-susceptible *S pseudintermedius*. Furthermore, although the overall prevalence of adverse effects secondary to antimicrobial drug treatment was 17.6% (38/216), 71% (27/38) of adverse effects were caused by chloramphenicol, which is usually reserved for treatment of antimicrobial-resistant infections.[4,8] Antimicrobial-resistant infections may also necessitate additional precautions, such as strict hygiene and physical separation from vulnerable persons (eg, infants and young children, the elderly, and the immunocompromised), that lead to additional cost and are a burden for patients' families. As Weese and van Duijkeren[9] note, "Regardless of the actual risk of zoonotic transmission, fear of transmission may have impacts on the human-animal bond and peoples' interaction with their pets."

Even as antimicrobial resistance has been increasing, the development of new antimicrobial drugs has slowed, and there have been efforts in other countries to prohibit veterinarians from using certain antimicrobial classes in their patients.[5,7] Faced with the prospect of increasing numbers of antimicrobial-resistant bacterial infections coupled with the dwindling number of drug choices and the possibility of bans on certain antimicrobial drugs, companion animal practitioners must adopt and implement hospital-level antimicrobial stewardship programs, such as those proposed by Guardabassi and Prescott,[5] the Task Force on Antimicrobial Stewardship in Companion Animal Medicine,[10] and the CDC for human outpatient settings.[11]

Importantly, antimicrobial stewardship involves more than simply judicious use of antimicrobial drugs at the time of prescribing. Veterinarians should take a holistic approach that views antimicrobial resistance from animal, human, and environmental health perspectives and incorporates a full spectrum of actions from an emphasis on preventive medicine that decreases the need for antimicrobial drugs, to

**Table 1**—Adverse effects of common antimicrobial drugs used to treat methicillin-resistant *Staphylococcus* and antimicrobial-resistant *Enterococcus* infections in dogs and cats.*

| Antimicrobial drug | Renal or hepatic toxicosis | Gastrointestinal effects* | Other adverse effects |
|---|---|---|---|
| Aminoglycosides | Renal | Rare | Ototoxicosis†<br>Neuromuscular blockade‡ |
| Chloramphenicol | Hepatic | Yes | Bone marrow suppression<br>Peripheral neuropathy (dog)§<br>Drug interactions |
| Rifampin | Hepatic | Yes | Thrombocytopenia<br>Hemolytic anemia<br>Discolored (orange) bodily fluids<br>Anaphylaxis (cat)† |
| Tetracyclines | Hepatic† | Yes‖ | Neutropenia (dog)† |

*Vomiting, diarrhea, anorexia, or weight loss. †Less common than other adverse effects. ‡When certain comorbidities or other medications (eg, anesthetic agents) are present. §Paresis, ataxia, and hind limb dysfunction. ‖Mainly vomiting or decreased appetite but may also cause esophagitis or esophageal stricture in cats.

evidence-based decision-making for antimicrobial prescribing, to monitoring and evaluating outcomes when antimicrobials are used. Stewardship efforts in companion animal practice are consistent with pledges in the Veterinarian's Oath to use one's knowledge and skills for "the protection of animal health and welfare [and] the promotion of public health" and they contribute to one-health efforts to combat antimicrobial resistance.[12,13]

## Local-Global Interconnectedness

The World Health Organization has noted that, "Given the ease and frequency with which people now travel, antimicrobial resistance is a global problem, requiring efforts from all nations and many sectors."[14] When people travel, they may bring animals with them as service or therapy animals or as companions. Families transport animals across the country and internationally when they relocate, and animal rescue organizations relocate animals in response to animal welfare concerns or after natural disasters such as the devastating hurricanes in Texas, Florida, and Puerto Rico in 2017.[15] Additionally, companion animals travel for agility or field trials, breed competitions, and police or military work, and breeders sell animals within and across state and national boundaries.

Antimicrobial resistance limits the ability of veterinarians and physicians to treat bacterial diseases, but it also threatens to undermine the United Nations' Sustainable Development Goals by jeopardizing good health and well-being through a reduced ability to treat bacterial infections and by compromising food and water safety through the presence and spread of antimicrobial-resistant pathogens.[16,17] Although more research needs to be done to characterize the relative contribution of companion animals to the spread of antimicrobial-resistant bacteria, antimicrobial stewardship in companion animal practice strengthens national and international public health efforts such as those by the CDC and the Global Health Security Agenda partners.[7,9,18]

## Biological Mechanisms of Resistance

Antimicrobial resistance is defined as "a property of microorganisms that confers the ability to inactivate or elude antimicrobials or a mechanism that blocks the inhibitory or killing effects of antimicrobials."[19] Some bacterial species have an inherent or innate resistance to certain classes of antimicrobials, referred to as intrinsic resistance, and clinicians should be aware of these intrinsic resistance patterns when choosing antimicrobials **(Table 2)**.[4,20] Acquired resistance refers to the situation when bacterial strains or subpopulations undergo changes that cause them to no longer respond to antimicrobials to which they were previously susceptible.[20] Acquired resistance typically develops as a result of selection pressure that occurs when bacterial pathogens and commensal microbiota are exposed to antimicrobial drugs.[7] Even when the use is considered therapeutic or judicious, antimicrobial drugs cause selection pressure that can lead to emergence or uncovering of resistant subpopulations of bacteria.[7,20] Because bacteria can acquire > 1 resistance gene, some bacterial strains carry resistance genes for > 1 drug.[20] In situations when a bacterial strain carries multiple antimicrobial resistance genes, exposure to one drug may amplify resistance to other drugs (known as coselection).[21] For example, a study[21] in pigs showed that through the mechanism of coselection, colonization with methicillin-resistant *S aureus* carrying both zinc and methicillin resistance genes increased even when pigs only received supplemental zinc.

For bacterial infections, antimicrobial susceptibility testing is a vital tool in helping veterinarians determine potential therapeutic options.[20] Because susceptibility testing is done in vitro and breakpoints are sometimes extrapolated from human medical standards, test results can only approximate in vivo conditions of patient infections; therefore, susceptibility testing must be done in accordance with stan-

**Table 2**—Intrinsic resistance patterns of bacterial organisms commonly isolated from dogs and cats.

| Organism | Aminoglycosides (eg, amikacin, gentamicin) | Ampicillin and amoxicillin | Ampicillin-sulbactam | Amoxicillin–clavulanic acid | First-generation cephalosporins (eg, cefazolin, cephalexin, cefadroxil) | Cefpodoxime and cefovecin | Chloramphenicol | Clindamycin | Macrolides (eg, azithromycin, erythromycin) | Nitrofurantoin | Penicillin | Rifampin | Tetracyclines (doxycycline, minocycline) | Trimethoprim-sulfamethoxazole |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anaerobic bacteria: *Clostridium* spp | X | | | | | | | | | | | | | |
| Anaerobic bacteria: *Bacteroides* spp | X | X | | | | | | | | | X | | | |
| *Enterococcus* spp | X | | | | X | X | | X | | | | | | X |
| *Escherichia coli* | | * | | * | | | | X | X | | | X | | |
| *Klebsiella pneumoniae* | | X | | | | | | X | X | | | X | | |
| *Klebsiella* (formerly *Enterobacter*) *aerogenes* | | X | X | X | X | | | X | X | | | X | | |
| *Proteus mirabilis* | | | | | | | | X | X | X | | X | X | |
| *Proteus vulgaris* | | X | | | X | | | X | X | X | | X | X | |
| *Pseudomonas aeruginosa* | | X | X | X | X | X | X | X | X | | X | X | X | X |

Modified, with permission, from Clinical Laboratory Standards Institute. *Performance standards for antimicrobial disk and dilution susceptibility tests for bacteria isolated from animals*. 4th ed. CLSI supplement VET08. Wayne, Pa: Clinical and Laboratory Standards Institute, 2018.

*Although *Escherichia coli* has no intrinsic resistance to ampicillin, amoxicillin, or amoxicillin–clavulanic acid, most isolates that are not from urine will be classified as resistant to ampicillin, amoxicillin, and amoxicillin–clavulanic acid on the basis of veterinary-specific susceptibility breakpoints for dogs and cats.

dard quality control procedures, and results must be interpreted on the basis of established standards, such as those from the Clinical and Laboratory Standards Institute (CLSI).[20] Newer methods for detecting antimicrobial resistance that may reduce testing time but are not yet widely used, in part because of cost, include automated susceptibility testing, resistance mechanism–specific testing (eg, chromogenic cephalosporinase testing for detecting β-lactamase production), and molecular detection techniques such as PCR assays and DNA hybridization to detect resistance genes.[20] Because of the time delay between submitting samples and receiving results of antimicrobial susceptibility testing, it has been suggested that veterinarians use cumulative antibiograms, which include susceptibility test results for bacteria found in a particular hospital, farm, or region, when selecting empiric treatment.[10,20] Unfortunately, although some veterinary antibiograms exist, they are not comprehensive or applicable to all geographic or practice areas, and care must be taken when using antibiograms to understand the underlying patient population used in their development and any possible bias in sample submission that might have been present (eg, the distribution of routine vs refractory case samples submitted).[10]

In some instances, veterinarians have used in-clinic bacterial culture kits, such as those marketed for testing of urine, to screen samples for bacterial growth and only sent samples with positive test kit results to an external laboratory for bacterial culture and susceptibility testing.[7] Use of these culture kits can aid in the diagnostic process by reducing turnaround time as well as the chance of bacterial overgrowth or loss of viability during shipping; however, kits should be validated in field studies for sensitivity, specificity, and accuracy prior to use.[7] Clinics attempting to perform full in-house bacterial culture and susceptibility testing should be aware that local or state legal requirements may bar such testing and that external laboratories incorporate quality control steps and safety precautions that may not be possible in general practice.[7] Failure to adhere to these standards may result in inaccurate results and health risks to staff.[7]

## Antimicrobial Resistance in Companion Animal Practice

Although the discovery of antimicrobials has been considered 1 of the 10 greatest public health achievements of the 20th century, human and animal health-care providers face the specter of no longer being able to treat previously simple and routine bacterial infections.[22] It is known that people, animals, and the environment can harbor bacteria with resistance genes, but more research needs to be done to understand exactly how these genes spread and their relative impact on human and animal health.[7,23] Veterinarians can help reduce bacterial selection pressure by following judicious use guidelines when prescribing antimicrobials; by promoting preventive strategies and alternatives to antimicrobials that re-

duce the need for these medications,[7,19] such as educating clients about animal husbandry and hygiene, nutrition, and vaccination; and by implementing infection control and quarantine practices, particularly in situations involving high animal densities such as shelters and breeding facilities.

Between 2013 and 2015, the AVMA's Task Force on Antimicrobial Stewardship in Companion Animal Practice set out to more fully understand the impact of and attitudes toward antimicrobial-resistant bacteria in companion animal medicine and to create approaches to address this problem.[10] This interdisciplinary group of professionals from clinical practice, government, industry, and the fields of infectious disease, pharmacology, and public health determined that companion animal practitioners are increasingly faced with treating multidrug-resistant bacterial infections in their patients, including infections with resistant strains of *E coli*, *Klebsiella* spp, and *Staphylococcus* spp.[3] The task force also found that although companion animal practitioners are increasingly aware of and concerned about the issue of antimicrobial resistance, they often do not feel equipped to take action. According to a survey of companion animal veterinarians conducted by the task force, 82% reported that they were somewhat or very concerned about antimicrobial resistance in dogs and cats. However, respondents also overwhelmingly desired more guidance in choosing the type of antimicrobial to use for an infection (77% strongly agreed or somewhat agreed) and in determining the most appropriate duration of antimicrobial administration (83% strongly agreed or somewhat agreed).[24]

In 2016, the AVMA developed the Committee on Antimicrobials to consolidate organizational efforts related to antimicrobial use in animals across the allied species groups, with committee members representing aquatic, bovine, companion animal, equine, poultry, small ruminant, and swine species groups as well as pharmacology and public health.[25] Among the committee's objectives were advising the AVMA on matters related to antimicrobial stewardship, collaborating with human medical organizations in a one-health approach to combat antimicrobial resistance, and providing tools and information to help species groups and individual veterinarians take action.[25] As a critical first step, the committee developed a policy document, Definition and Core Principles of Antimicrobial Stewardship in Veterinary Medicine, that the AVMA House of Delegates unanimously approved as policy in January 2018. The document defines antimicrobial stewardship as "the actions veterinarians take individually and as a profession to preserve the effectiveness and availability of antimicrobial drugs through conscientious oversight and responsible medical decision-making while safeguarding animal, public, and environmental health."[26] Further, the core principles of antimicrobial stewardship were based on the premise that "Antimicrobial stewardship involves maintaining animal health and welfare by implementing a variety of preventive and management strategies to prevent common diseases; using an evidence-based approach in making decisions to use antimicrobial drugs; and then using antimicrobials judiciously, sparingly, and with continual evaluation of the outcomes of therapy, respecting the client's available resources."[26]

## Social and Behavioral Determinants of Adoption of Antimicrobial Stewardship Principles

An effective antimicrobial stewardship plan requires an understanding of barriers to improving disease prevention and to cultivating appropriate antimicrobial prescribing and usage at the practitioner level as well as barriers to acceptance and compliance at the client level. In human medicine, client pressure and clinician habits have been suggested to influence prescribing habits, as have health-care providers' geographic locations and settings.[27–30] For example, Fleming-Dutra et al[28] found that 30% of antimicrobial prescriptions in US doctors' offices and emergency rooms were unnecessary and that improvements could have been made in drug selection, dose, or duration for the remaining 70%. Regional prescribing habits by human health-care providers in outpatient settings show variations by state, and these data allow public health agencies to target educational campaigns to areas where unnecessary prescribing is more common.[27]

Comprehensive surveys of antimicrobial prescribing behavior in companion animal practice are lacking; however, some self-reported survey data and studies at veterinary teaching hospitals or in discrete geographic areas provide insight into prescribing behavior prior to referral.[31–33] Baker et al[31] found that 55.6% of dogs admitted to a veterinary teaching hospital had received an antimicrobial drug in the 12 months prior to admission. In that study, 85% of dogs admitted to the hospital had an existing medical problem, and dogs with an existing medical problem were twice as likely as healthy dogs to have recently received an antimicrobial drug. In addition, 72.4% of the dogs admitted to the hospital had been referred by a veterinarian because of a past medical problem, and the odds that these dogs received an antimicrobial drug within 30 days prior to hospital admission were 2.39 times those for dogs that had not been referred. In another study,[32] primary care veterinarians in Ontario self-reported mainly using antimicrobials classified as first-line options (eg, β-lactams such as cephalexin and amoxicillin–clavulanic acid), but also reported using some drugs described as second-line options (eg, fluoroquinolones and cefovecin), whose use has been recommended to be reserved following failure of first-line treatment and with the support of bacterial culture and antimicrobial susceptibility testing.[32,33] On the basis of these findings,

the study authors suggested that progress could be made in reducing the use of antimicrobials, particularly in cats with upper respiratory tract disease or lower urinary tract disease and in dogs with infectious tracheobronchitis.[32]

Although many veterinarians are aware that bacterial culture and susceptibility testing are recommended prior to prescribing antimicrobials drugs to optimize drug choice, testing may be costly, and patient health status may dictate that antimicrobials be started before results would be available. Moreover, most companion animals are not covered by insurance, and most veterinarians mainly depend on a fee-for-service model. Thus, an owner's budgetary concerns can limit a practitioner's ability to adhere to guidelines related to susceptibility testing. In the survey conducted by the AVMA's Task Force on Antimicrobial Stewardship in Companion Animal Practice, 84% of veterinarians reported that the cost of bacterial culture and susceptibility testing was a barrier to judicious antimicrobial use.[24] A study[32] of companion animal veterinarians in Ontario found that only 4% of antimicrobial prescriptions were preceded by bacterial culture and susceptibility testing, which was explained by concerns about the added cost and the delay between diagnosis and prescription.

Although patient compliance and adherence to treatment directions are important concerns in both human and veterinary medicine, companion animal veterinarians have the added complication of ensuring that caregivers are able to administer medications and that patients don't resist taking them. Because of lack of medication palatability, aggressive patient demeanor, and high frequency of dosing (eg, 3 times daily vs twice or once daily), clients may give antimicrobials at a lower frequency or for a shorter duration than recommended, which may contribute to development of antimicrobial-resistant strains of bacteria.[34] Because administering medications orally in cats can be notoriously difficult, cefovecin, which is administered as an SC injection, may be the only viable option for treating susceptible bacterial infections in some patients, despite its designation by some as a second-line option.[32,33] Nevertheless, stewardship principles emphasize that clinicians should choose an antimicrobial drug on the basis of its predicted activity against the suspected pathogen, the amount of active drug that can reach the site of infection, patient factors such as renal or hepatic function, potential drug interactions, and recommendations to limit the use of third-generation cephalosporins and fluoquinolones.[7,19,32,33] For judicious use of antimicrobials, medical necessity and patient, drug, and disease considerations should be given greater weight than doctor preference or client convenience. Because many respondents to the survey by the AVMA's Task Force on Antimicrobial Stewardship in Companion Animal Practice both desired more guidance regarding the choice and duration of antimicrobial therapy (77% and 83% of respondents, respectively) but were not aware of existing guidelines (88% of respondents),[24] an opportunity exists to educate and raise awareness in companion animal practitioners that can be met by veterinary professional groups, continuing education providers, and state veterinary medical boards and associations.

## Current Public Health Interventions

Current federal regulations restrict how certain antimicrobials important in human medicine are prescribed or dispensed to food-producing animals. This includes drug classes commonly used in companion animal practice (eg, penicillins, cephalosporins, and fluoroquinolones). Since January 2017, the FDA has required veterinary oversight for dispensing of these medically important antimicrobials in food and water, and indications for use to promote growth and increase feed efficiency have been voluntarily removed from the labels of medically important antimicrobials by pharmaceutical companies.[35] State veterinary medical boards require a valid veterinarian-client-patient relationship to ensure adequate veterinary oversight when prescribing medications, including antimicrobials; however, similar regulatory prohibitions on the use of antimicrobials important in human medicine do not currently exist for companion animals. Establishing a veterinarian-client-patient relationship requires that the veterinarian assumes responsibility for making clinical judgments about an animal's care, the client agrees to follow the veterinarian's instructions, and the veterinarian has sufficient knowledge of the patient to be able to make diagnoses; oversee treatment, compliance, and outcome; provide follow-up; and maintain medical records for the patient.[36]

There is a growing body of condition-specific guidelines that provide evidence-based ways to decrease antimicrobial prescribing,[37–41] and various veterinary professional organizations and interagency working groups have also published broad consensus statements, guidelines, and core principles.[7,10,19,26,42] At the federal level, the CDC's and USDA's one-health offices coordinate efforts to combat antimicrobial resistance, and along with the FDA, these agencies collaborate on public health surveillance through the National Antimicrobial Resistance Monitoring System, which "tracks changes in the antimicrobial susceptibility of certain enteric (intestinal) bacteria found in ill people (CDC), retail meats (FDA), and food animals (USDA) in the United States."[43] Unfortunately, this system tracks information on a relatively limited number of bacteria, and no such surveillance system exists for companion animals. Finally, veterinary researchers and public health organizations continue to investigate the biological mechanisms of antimicrobial resistance and methods for the spread of resistant bacteria and work to get the public and health-care providers involved (eg, US Antibiotic Awareness Week).[44]

## Relevant Policies

Following the increased veterinary oversight of antimicrobial drugs in food-producing animals, the FDA has indicated its intent to develop strategies to promote antimicrobial stewardship in companion animal practice but has not specified whether the agency would place restrictions on the antimicrobial drugs veterinarians could use in their patients.[45–47] Many antimicrobial drug classes designated by the World Health Organization as medically important in treating humans are also commonly used in companion animal medicine, including cephalosporins, fluoroquinolones, lincosamides (eg, clindamycin), macrolides (eg, azithromycin), penicillins, and tetracyclines.[48] Two antimicrobial classes commonly used in companion animal practice (ie, third-generation cephalosporins, such as cefpodoxime and cefovecin, and fluoroquinolones) are considered by the World Health Organization to be critically important to human medicine and of the highest priority for prudent use.[48] If regulations were imposed that prevented companion animal veterinarians from using these essential medications, the ability to treat routine and serious illnesses in companion animals would likely be compromised.

Veterinary professional organizations and task forces in the United States and globally affirm that "veterinarians should lead the decision-making process for the use of antimicrobials in animals."[49] In its Consensus Statement on Therapeutic Antimicrobial Use in Animals and Antimicrobial Resistance, the American College of Veterinary Internal Medicine has cautioned that the veterinary profession must take a proactive approach to antimicrobial stewardship "to avoid mandatory restrictions by regulatory bodies."[7] Finally, the AVMA has adopted a definition of antimicrobial stewardship and core principles for antimicrobial stewardship in veterinary medicine[26] in the hope that this shared framework of core principles will demonstrate the veterinary profession's commitment to the promotion of antimicrobial stewardship.

## Proposed Solutions

Given the ongoing concerns about antimicrobial resistance, companion animal veterinarians have an obligation to help better understand current patterns of antimicrobial use and resistance, adapt antimicrobial stewardship frameworks for use in their hospitals, and engage in dialog with state and federal agencies on antimicrobial prescribing practices. A previous study[33] suggested that veterinary hospitals and clinics can improve prescribing practices by developing antimicrobial guidelines for their own use. Practitioners can use the AVMA's Core Principles of Antimicrobial Stewardship,[26] clinician and facility checklists in the CDC's Core Elements of Outpatient Antibiotic Stewardship,[11] and other guidelines, such as those by Guardabassi and Prescott,[5] to develop antimicrobial stewardship plans for their own hospitals **(Figure 1)**.

Veterinary hospitals that commit to antimicrobial stewardship should designate a person to lead the hospital effort, hold all employees accountable to practice decisions, and help the practice team decide where they should focus their efforts. Practices can focus on a common type of case, such as respiratory illness, urinary tract disease, or superficial bacterial folliculitis, for which there are published guidelines; hospital protocols for diagnostic testing, such as bacterial culture and susceptibility testing or use of urine dipsticks; or improving hospital infection control processes.[7,37–42] Hospitals can publicly demonstrate the practice's commitment to antimicrobial stewardship with a posted, personalized statement that indicates the hospital will prescribe antimicrobials only when they are indicated and will avoid use of them when they are not indicated (eg, viral infections) and that explains to clients the connection between antimicrobial use and resistance.[50] This simple and inexpensive action has been shown in a randomized clinical trial of 5 outpatient primary care clinics to significantly reduce inappropriate prescribing.[51] In their report, the

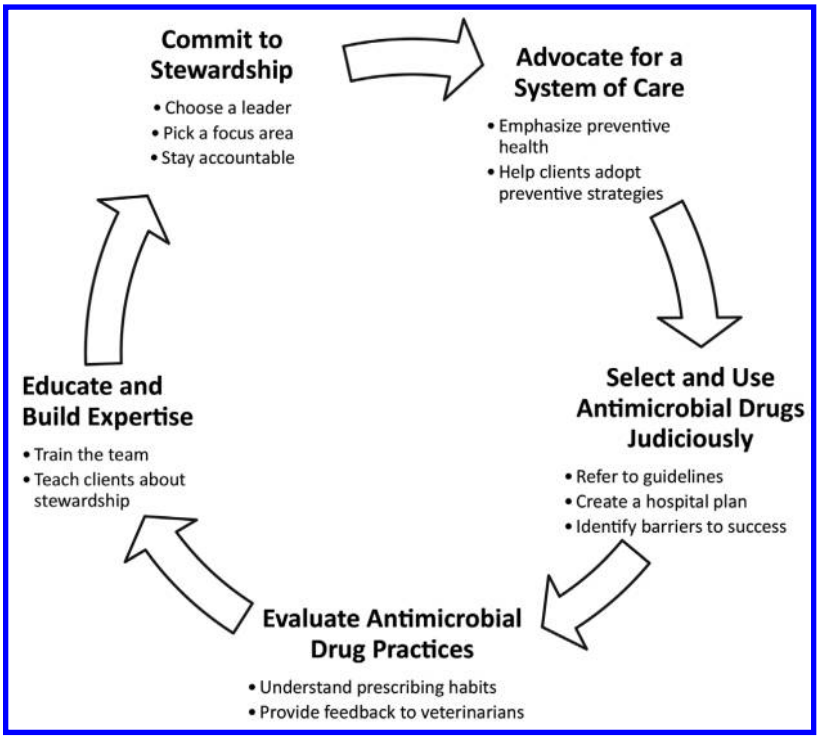


**Figure 1**—Illustration of a method for continuous development of an antimicrobial stewardship plan in veterinary practice. Adapted from the AVMA. Antimicrobial stewardship: definition and core principles. Available at: www.avma.org/KB/Policies/Pages/Antimicrobial-Stewardship-Definition-and-Core-Principles.aspx. Accessed April 23, 2018. Reprinted with permission.

authors suggested that posted letters may have made clients less demanding of antimicrobials as a result of increased awareness of antimicrobial use concerns or their desire to uphold their doctor's commitment and may have caused doctors to perceive clients as less demanding of antimicrobials because of their own expectations of the letter's effectiveness.[51]

Because stewardship encompasses more than just the decisions clinicians make about when and what to prescribe, practices should also emphasize preventive medicine practices, such as vaccination, nutrition, and animal husbandry, that can reduce the need for antimicrobial drugs.[26] They should also evaluate current antimicrobial drug use practices in the hospital and compare those practices to published guidelines and consensus statements.[7,19,26,39–42] From this evaluation, practices can create protocols to select and use antimicrobial drugs judiciously and also identify potential obstacles (eg, client pressure, lack of adoption by the practice team, or cost of diagnostic testing) and how the practice will address them.[26] For veterinarians to understand trends in their practice, practice stewardship plans should include a mechanism to document and communicate indicators of stewardship to their veterinary team.[26] These might include how often antimicrobial drugs are prescribed, how often bacterial culture and susceptibility testing is performed, the types and frequency of resistant bacteria identified, or the incidence of adverse effects resulting from antimicrobial use.[10,26]

Once the practice team has developed protocols, the designated leader will need to educate team members about stewardship principles and the hospital protocols and guide them to available continuing education resources on antimicrobial resistance.[20,26] Consideration should also be given to educating clients including breeders and pet store owners, whose understanding and compliance is critical for the success of the hospital plan.[26,52] Because a recent study[53] of companion animal veterinarians and their clients demonstrated that each group attributed the pressure to prescribe to the other, veterinarians should recognize the potential for these mismatched perceptions when they create a communication plan. Finally, practices should evaluate how well they have been able to comply with their antimicrobial stewardship strategy and regularly reaffirm their commitment. This also gives the practice team a chance to choose the next area on which to focus their efforts. When practices view a hospital stewardship plan as a continuous improvement process, they are motivated to keep it current and to consider new guidelines as they are released.[5]

To ensure the success of antimicrobial stewardship plans in companion animal practices, veterinarians will need support from all levels of the socioecological model of health **(Figure 2)**. Professional organizations and policy makers can play a crucial role in supporting practitioners in creating and implementing antimicrobial stewardship programs and in reducing barriers to their use.[5] Veterinary professional groups, industry, clinical laboratories, academic institutions, public health organizations, and those who fund research should work together to reduce barriers to antimicrobial susceptibility testing in companion animal practice, such as through collaborations on laboratory standards, including development of interpretive breakpoints for determining susceptibility or resistance to antimicrobials; reducing the time between laboratory submission and test results through the use of automated systems, mechanism-specific PCR assays, and DNA hybridization; and developing and expanding regional antibiograms to offer veterinarians information on appropriate empiric treatment while waiting for bacterial culture and susceptibility testing results. Challenges include costs associated with newer forms of diagnostic testing and the potential for bias in the development of antibiograms.[10,19] To fill the gaps in the education of veterinarians and their clients, public health and veterinary professional organizations should develop and disseminate educational materials to help reduce unnecessary prescriptions and improve compliance, such as those developed by the Task Force on Antimicrobial Stewardship in Companion Animal Practice and the CDC.[37,38,52,54] Organizations with existing guidance documents on judicious use of antimicrobials, such as the American Association of Feline Practitioners and the American Animal Hospital Association, should review and expand those documents to reflect new work by the AVMA Committee on Antimicrobials. Likewise, organizations, such as the International Society for Companion Animal Infectious Diseases, should continue to develop condition-specific guidelines applicable to companion animal practice.[39–41] Research is also needed into barriers to antimicrobial stewardship in companion animal practice, mechanisms to address or overcome these barriers, and determinants of suc-

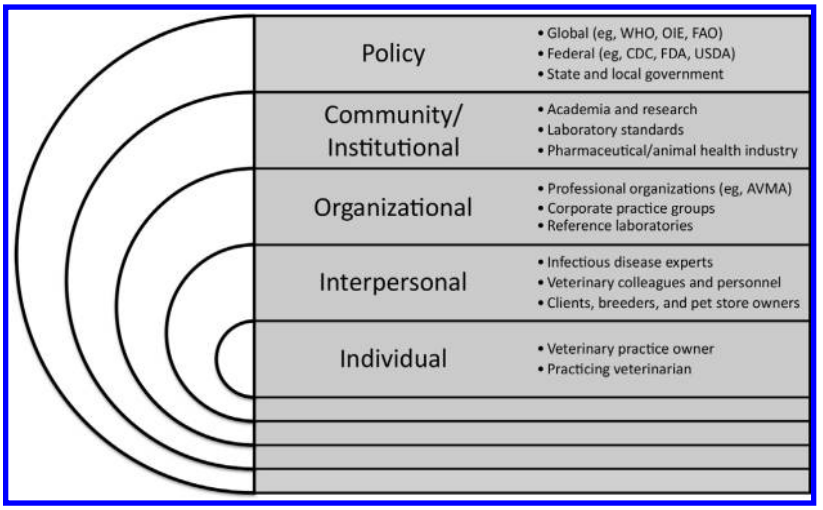


**Figure 2**—Adaptation of the socioecological model of health to understand the levels of support needed for the successful implementation and sustainability of antimicrobial stewardship plans in companion animal veterinary medicine.

cessful implementation of practice-level antimicrobial stewardship programs. In addition, more information is needed on veterinary-specific antimicrobial susceptibility breakpoints, the most appropriate doses and durations for antimicrobial drugs in companion animals, the incidence of antimicrobial resistance in companion animals, and the spread of antimicrobial resistance genes among bacteria affecting people, animals, and the environment.[8] Finally, one-health efforts to address antimicrobial resistance at the local, national, and global levels are strengthened when veterinarians encourage clients to properly dispose of unused antimicrobials[55] and engage in intersectoral antimicrobial stewardship working groups.

## Conclusions

Companion animal veterinarians are not immune to the challenges of antimicrobial resistance and have obligations to both protect the health and welfare of their patients and promote public health. The challenge of antimicrobial resistance crosses species and geographic boundaries, and although much of the attention in the past has focused on food-producing animals, companion animal practitioners also have important roles to play in preserving the effectiveness and availability of antimicrobial drugs. Companion animal practitioners must commit to antimicrobial stewardship in their practice, but they should also engage in discussions on the state and federal levels to ensure continued access to antimicrobial drugs of importance in veterinary medicine. By engaging with organizations in the human medicine, environmental health, and public health fields, companion animal veterinarians can make their perspective heard, promote the health and welfare of their patients and the public, and shift the conversation about antimicrobial resistance toward a collaborative one-health approach.

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