Antibiotic Resistance in Veterinary Practice: A Growing Threat to Animal and Public Health

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Abstract

Antibiotic resistance has emerged as one of the greatest challenges in veterinary medicine, threatening animal health, livestock productivity, food safety and public health. The irrational and excessive use of antibiotics has accelerated the development of resistant bacterial pathogens, resulting in treatment failures and increased economic losses. Adopting evidence-based prescribing practices and integrated disease prevention measures is essential to preserve antibiotic efficacy, improve therapeutic outcomes and ensure sustainable animal production while protecting both animal and human health.

Keywords Antimicrobial resistance; Antibiotic stewardship; Livestock health; One Health

Introduction

Antibiotics have transformed veterinary medicine by enabling effective treatment of bacterial infections, improving animal welfare, increasing livestock productivity and reducing economic losses. However, their indiscriminate and irrational use has accelerated the emergence of antimicrobial resistance (AMR), one of the most significant global health challenges of the 21st century. Antimicrobial resistance occurs when bacteria evolve mechanisms that enable them to survive exposure to antibiotics that were previously effective.

Veterinary professionals play a crucial role in combating AMR because antibiotics are widely used in companion animals, dairy cattle, poultry, pigs, sheep, goats and aquaculture. Resistant bacteria can spread among animals, humans and the environment through the One Health pathway, making AMR not only a veterinary concern but also a major public health issue.

Understanding Antibiotic Resistance

Antibiotic resistance develops when bacteria undergo genetic changes that reduce or eliminate the effectiveness of antimicrobial drugs. These changes may arise through spontaneous mutations or by acquiring resistance genes from other bacteria via plasmids, transposons, or bacteriophages. Bacteria develop antibiotic resistance through several mechanisms that reduce or eliminate the effectiveness of antimicrobial agents. These include the production of enzymes, such as β-lactamases, that inactivate antibiotics by breaking down their chemical structure; modification of antibiotic target sites, preventing effective drug binding; reduced permeability of the bacterial cell wall or membrane, which limits antibiotic entry into the cell; activation of efflux pumps that actively expel antibiotics before they reach therapeutic concentrations; and the formation of biofilms, which create a protective matrix that shields bacterial communities from antimicrobial agents and host immune defenses. These resistance mechanisms may occur individually or in combination, making bacterial infections increasingly difficult to treat in veterinary practice.

Once resistant bacteria emerge, they multiply rapidly and may spread between animals, farms, veterinary hospitals and even humans.

Causes of Antibiotic Resistance in Veterinary Practice

Several management and therapeutic practices contribute to AMR. Like irrational antibiotic use, empirical therapy without diagnosis, incorrect dosage and duration, indiscriminate prophylactic use, poor farm management

Common Resistant Pathogens in Veterinary Medicine

Several bacterial pathogens of veterinary importance have developed resistance to multiple classes of antibiotics, posing a major challenge to disease management. Among these, Staphylococcus aureus, including methicillin-resistant strains (MRSA), is a significant cause of mastitis, wound infections and skin diseases that are often difficult to treat. Other important multidrug-resistant bacteria include *Escherichia coli*, commonly associated with enteritis, urinary tract infections and septicemia; *Salmonella enterica*, an important foodborne pathogen with zoonotic potential; *Klebsiella pneumoniae*, a frequent cause of mastitis and respiratory infections; Pseudomonas aeruginosa, an opportunistic organism known for its intrinsic resistance to numerous antimicrobials; and *Pasteurella multocida*, which is responsible for respiratory diseases and hemorrhagic septicemia in livestock. The emergence and dissemination of multidrug-resistant strains of these pathogens significantly limit therapeutic options, increase treatment failures and threaten both animal and public health.

These organisms are responsible for mastitis, respiratory diseases, urinary tract infections, wound infections, septicemia and enteric diseases in livestock and companion animals.

Impact on Animal Health

Antibiotic resistance has profound consequences for veterinary practice by reducing the effectiveness of antimicrobial therapy and compromising animal health and productivity. Resistant bacterial infections often result in delayed clinical recovery, prolonged duration of illness, frequent treatment failures and increased mortality. These infections necessitate the use of more expensive second-line or critically important antibiotics, thereby substantially increasing treatment costs for livestock owners. In food-producing animals, antimicrobial resistance is associated with reduced milk yield, decreased meat and egg production, impaired feed efficiency and poor reproductive performance, leading to significant economic losses. Furthermore, the persistence and spread of resistant pathogens increase the risk of disease transmission within herds and pose a serious threat to food safety and public health under the One Health framework.

In dairy cattle, resistant mastitis pathogens reduce milk quality and increase economic losses. In poultry, resistant bacterial infections may result in poor feed conversion, decreased weight gain and increased mortality.

Public Health Concerns

The emergence of antibiotic-resistant bacteria in animals has significant implications for human health because resistant pathogens and their resistance genes can spread across species through multiple transmission routes. Humans may acquire these organisms through the consumption of contaminated milk, meat, eggs and other animal-derived food products, direct contact with infected or carrier animals, exposure to contaminated soil and water containing animal waste and veterinary hospital-associated infections. This interconnected transmission underscores the importance of the One Health approach, which recognizes that the health of humans, animals and the environment is closely linked.

Consequently, effective control of antimicrobial resistance requires coordinated efforts among veterinarians, physicians, microbiologists, environmental scientists, farmers, public health authorities and policymakers to promote the judicious use of antibiotics, strengthen surveillance systems, improve biosecurity and implement integrated disease prevention strategies.

Diagnosis before Treatment

Judicious antibiotic use begins with accurate diagnosis.

Veterinarians should perform:

- Detailed clinical examination.
- Sample collection before initiating antibiotics.
- Bacterial culture.
- Antimicrobial susceptibility testing (AST).
- Hematological and biochemical evaluation when required.

Culture and sensitivity testing enables selection of the most effective antibiotic while reducing unnecessary antimicrobial exposure.

Principles of Rational Antibiotic Use

Veterinarians should adhere to the principles of antimicrobial stewardship to ensure the responsible and judicious use of antibiotics. Antibiotics should be prescribed only for confirmed or strongly suspected bacterial infections, with treatment preferably guided by bacterial culture and antimicrobial susceptibility testing. Whenever appropriate, narrow-spectrum antibiotics should be selected to minimize the development of resistance and preserve the normal microbial flora. Successful therapy also depends on administering the correct antibiotic at the appropriate dose, route and duration, while ensuring that the prescribed treatment course is completed. Unnecessary combination therapy should be avoided unless clinically justified. In food-producing animals, strict adherence to recommended withdrawal periods is essential to prevent antibiotic residues in milk, meat and other animal products. Additionally, maintaining accurate treatment records facilitates disease monitoring, antimicrobial surveillance and promotes responsible antibiotic use in veterinary practice.

Antimicrobial Stewardship

Antimicrobial stewardship encompasses a coordinated set of strategies designed to optimize the use of antibiotics while minimizing the emergence and spread of antimicrobial resistance. It promotes the responsible selection, dosage and duration of antimicrobial therapy to achieve the best clinical outcomes while preserving the effectiveness of existing antibiotics. The key components of antimicrobial stewardship include the implementation of standard treatment guidelines, strengthening infection prevention and farm biosecurity measures, routine vaccination programs to reduce disease incidence, regular surveillance of antimicrobial resistance patterns, continuous education and training of veterinarians and farmers on prudent antibiotic use and systematic monitoring of antimicrobial consumption. Together, these measures improve treatment success, reduce the selection pressure for resistant bacteria, safeguard animal and public health and preserve the efficacy of antibiotics for future generations.

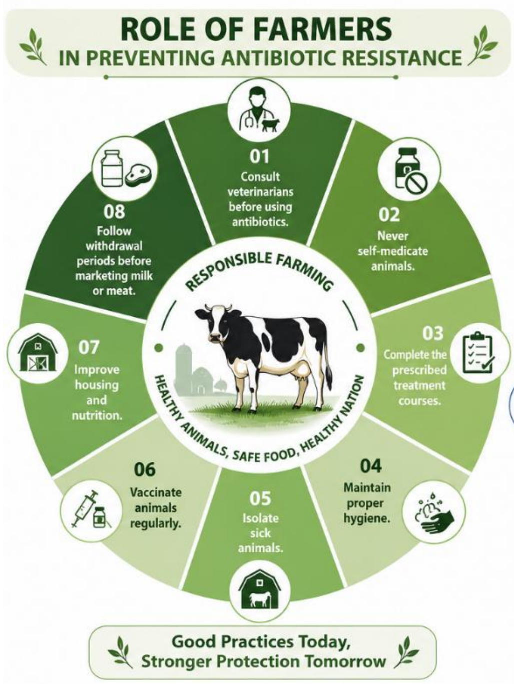
Alternatives to Antibiotics

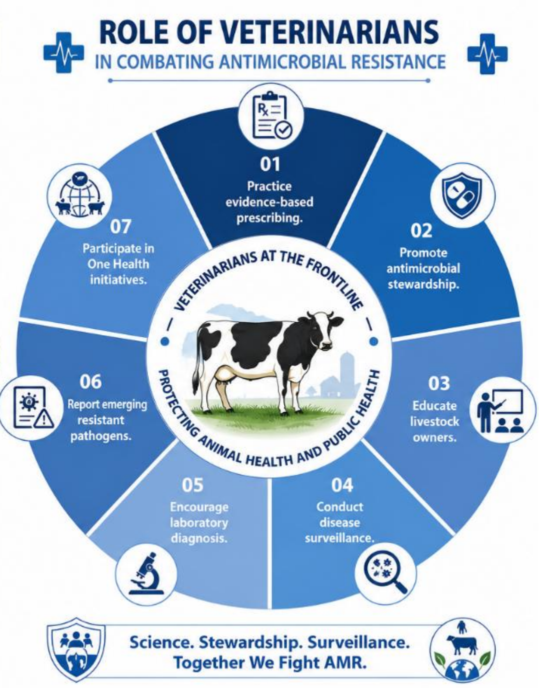
Reducing dependence on antibiotics requires an integrated approach that emphasizes disease prevention, improved animal health and sustainable management practices. Vaccination remains one of the most effective strategies for preventing infectious diseases and minimizing the need for antimicrobial therapy. Other promising alternatives include the use of probiotics and prebiotics to enhance gut health and immunity, competitive exclusion products to inhibit colonization by pathogenic bacteria, balanced nutrition to improve disease resistance and enhanced farm biosecurity to reduce pathogen exposure. In dairy herds, selective dry cow therapy helps decrease unnecessary antibiotic use without compromising udder health. Emerging alternatives such as phytogenic feed additives, bacteriophage therapy, antimicrobial peptides and immunomodulators have also shown considerable potential in controlling bacterial infections while reducing reliance on conventional antibiotics. The integration of these preventive and non-antibiotic approaches can significantly decrease antimicrobial use, improve animal health and productivity and contribute to mitigating the development and spread of antimicrobial resistance.

Although these alternatives cannot completely replace antibiotics, they substantially reduce the need for antimicrobial treatment.

Future Perspectives

Rapid molecular diagnostics, whole-genome sequencing, artificial intelligence-based surveillance and precision livestock farming are transforming infectious disease management. Improved vaccines, novel antimicrobials, bacteriophage therapy and





CRISPR-based antimicrobial technologies offer promising avenues for combating resistant bacteria. Strengthening antimicrobial surveillance and enforcing national antibiotic policies will be essential for sustainable livestock production.

Conclusion

Antibiotic resistance is one of the greatest challenges facing modern veterinary medicine. The indiscriminate use of antibiotics threatens animal health, food safety and public health by reducing treatment effectiveness and promoting the spread of resistant bacteria. Rational antibiotic use, accurate diagnosis, antimicrobial stewardship, improved biosecurity, vaccination and farmer education are essential to preserve the efficacy of existing antibiotics. By embracing the One Health approach, veterinarians can play a pivotal role in safeguarding both animal and human health while ensuring sustainable livestock production for future generations.