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From Farm to Future: The Escalating Threat of Antibiotic Resistance in Animal Systems

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Abstract

Antibiotic resistance (AR) is a complex, multidimensional global health problem that endangers people, animals, and the environment. Antimicrobial medications lose some of their ability to inhibit or stop the growth of bacteria as they become more resistant to them. This hazard is caused by a number of factors, including drug abuse and overuse, inadequate hygiene, ignorance, and production pressure. greater animal suffering, greater mortality, decreased output, and financial losses follow from this. Antibiotic-resistant bacteria (ARB) can spread due to the interconnectedness of cattle, human, and environmental components, which is why it is considered a One Health concern. To successfully address this issue, a coordinated One Health approach is necessary. By focusing on preventive measures, responsible use of antibiotics, and improved management practices, it is possible to combat antibiotic resistance and ensure a healthier future for both animals and humans.

Key Words: Antibiotic resistance, Antibiotic-resistant bacteria, One Health approach, Antibiotics

1. Introduction

One of the most effective therapeutic approaches in medical history, antibiotics have been integral to contemporary medicine. Antimicrobial usage in food animals was projected to be 63,151 tons (± 1650) tons worldwide in 2010 and 131,109 tons in 2013. About 34% of the rise in global consumption can be attributed to the increased use of antimicrobials in intensive production systems (Van et al., 2015). India contributes for roughly 3% of the world's use of antimicrobials in food animals, with a projected increase of up to 200,235 tons by 2030 (Van et al., 2015). Cattle, poultry, and pigs are examples of food animals that are



widely raised throughout the world for both food and financial gain. Because of the quickly rising demand for cattle products brought on by urbanization and population increase, the modes of production are intensive. Antibiotic resistance has increased as a result of the unchecked use of antibiotics and antimicrobials.

The health of both humans and animals is increasingly threatened by antimicrobial resistance (AMR). One of the main causes of resistance development in both the medical and veterinary fields has been the improper and prolonged use of antibiotics, especially in the treatment of chronic illnesses. This convergence reduces the effectiveness of current antimicrobial drugs by hastening the emergence and spread of resistant infections. The World Health Organization (WHO) has classified antimicrobial resistance (AMR) as a global health emergency and listed it as one of the top ten risks to world health due to its potential to cause millions of deaths each year (Murray et al., 2022).

The issue of misuse of antibiotics and AMR in livestock is more prevalent in developing countries due to unregulated antibiotic sales, underdeveloped healthcare infrastructure, overuse and misuse of antibiotics for non-therapeutic growth promotion, indiscriminate and irrational use without following the withdrawal period, among others (Hosain et al., 2021).

2. Antibiotics: Initial concepts

The Greek terms *anti* (against) and *bios* (life) are the roots of the word "antibiotic." These are microbial metabolites with a low molecular weight that prevent other microbes from growing at low quantities. They can be either naturally occurring or semi-synthetic organic solids. Antibiotics are frequently utilized in the current healthcare system in both human and animal sciences, and they are among the most effective life-saving treatments in all of

medicine. Perhaps the biggest medical advancement of the 20th century was the introduction of antibiotics into clinical practice. By preventing the activity of a molecule, typically a macromolecule like an enzyme or nucleic acid, they prevent the growth of susceptible microorganisms. Beta-lactams, tetracyclines, aminoglycoside antibiotics, macrolides, and ansamycins are among the various classes of antibiotics.

3. Antibiotic Resistance

The World Health Organization (WHO) defines antimicrobial resistance (AMR) as "an increase in the minimum inhibitory concentration of a compound for a previously sensitive strain" (WHO, 2013). It mostly refers to a microbe's capacity to evade the effects of an antibiotic despite being exposed to appropriate dosages. When bacteria have genetic alterations that allow them to withstand exposure to antibiotics that would typically kill them



or stop their growth, this is known as antibiotic resistance. Standard therapies become ineffective as a result, which raises mortality rates, lengthens illness, and makes diseases more severe. Antibiotic abuse and overuse in both human and veterinary medicine significantly accelerates the natural development of this resistance over time. As a result, infections that were previously curable become challenging or even unmanageable. According to the Lancet Commission, it is one of the numerous issues of the twenty-first century that could impede future advancements in global health (Kanem et al., 2023).

Resistance from antibiotics is a complex and interconnected issue, where, the drugs once considered highly effective in treating infections, are gradually losing their efficacy because bacteria are developing resistance against them. This situation has serious consequences for animal health, welfare, food production, public health and overall environment. Therefore, the issue must be approached through a holistic One Health framework, which emphasizes the interdependence of human, animal, and environmental health.

4. Antibiotic Resistance in livestock

Three main reasons drive the use of antibiotics in livestock: to cure illnesses, to keep animals at risk of infection, or as feed additives to promote growth. Many studies have shown a connection between AR in humans who live on or near farms and the use of antibiotics in food-producing animals, particularly for growth promotion. Antibiotic resistance in food animals is considered an emerging contaminant that is a major danger to public health worldwide (Xu et al., 2022). Antibiotic-resistant bacteria (ARB) and pathogenic zoonotic bacteria like *Staphylococcus aureus* (S. aureus), *Salmonella* species, *Campylobacter* species, *E. coli*, and *Listeria* species can be found in livestock ranches. These bacteria can spread into the environment through slurry, air, and animal excrement, which could result in an illness outbreak.

5. Potential causes of Antibiotic Resistance

In animals, antibiotic resistance can increase the risk of complications, raise the cost and complexity of care, and allow resistant bacteria to spread between animals, humans and the environment. The potential drivers of antibiotic resistance in shown in figure 1.

Over time, bacteria naturally develop resistance to drugs. However, several elements

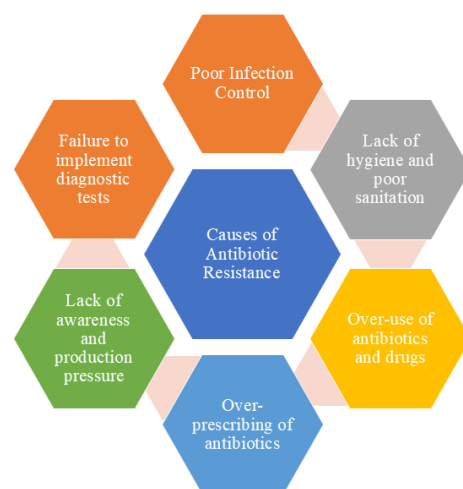


Figure 1: Key drivers of antibiotic resistance in animal system



can expedite the procedure, such as: Antibiotic residues and resistant bacteria discharged in animal excrement contaminate soil and water, as do overuse and misuse of antibiotics for growth promotion and disease prevention or prophylaxis, inadequate hygiene and sanitation, and improper prescription prescribing. The following are a few biological processes that lead to antibiotic resistance: Horizontal gene transfer, spontaneous changes, genetic mutations in microorganisms, and natural selection with protective genetic features.

Apart from the above-mentioned causes, some socio-economic and regulatory factors are also responsible for antibiotic resistance to occur. Lack of oversight as antibiotics are available over the counter without a veterinarian's prescription causing unregulated use, intensive farming systems which often faces greater disease pressure and economic pressure as farmers use antibiotics to mask poor management practices or to maximize profits through increased yield. The subsequent contamination of soil, sediments, sludge, groundwater, wastewater, tap and surface water, and plants contribute to the emergence and spread of multi-drug (MDR) organisms in environment. Together, these factors accelerate the emergence and dissemination of antibiotic resistance.

6. Impact of antibiotic resistance

Animal Health and Welfare: Antibiotic resistance has a direct and serious impact on animal health and welfare by reducing the effectiveness of treatments. When infections cannot be treated successfully, animals experience prolonged illness, increased suffering, and a higher risk of death. In severe cases, euthanasia may become necessary to prevent further pain and distress. This not only raises ethical concerns but also highlights the importance of effective disease management in maintaining animal welfare.

Companion Animals: Companion animals such as dogs, cats, and horses are significantly affected by antibiotic resistance. These animals often suffer from infections caused by resistant bacteria, which are difficult to treat and may require prolonged or complex therapies. As a result, recovery periods are extended and treatment outcomes become uncertain. The loss of service animals can also disrupt the daily lives of individuals who depend on them.

Veterinary Clinics and Hospitals: Veterinary clinics and hospitals can be significantly affected by outbreaks of antibiotic-resistant bacteria. Such outbreaks may require extensive infection control measures, including decontamination and temporary closure of facilities, which can lead to considerable financial losses. Additionally, these situations increase the cost of diagnostics and treatments and may damage the reputation of the institution, resulting in loss of client trust.



Food-Producing Animals: Antibiotics are commonly used in these animals for the treatment and prevention of infectious diseases. In intensive farming systems, where animals are kept in close proximity, the risk of disease transmission is particularly high. Consequently, resistance can have a widespread impact on animal health and agricultural output. Examples include mastitis in dairy cattle becoming resistant to penicillin, respiratory diseases in livestock showing resistance to common antibiotics, and swine dysentery becoming difficult to control due to multidrug resistance.

Economic Impact on Food Production: The economic consequences of antibiotic resistance in food production are substantial. Farmers face increased veterinary costs due to the need for more expensive or prolonged treatments. At the same time, reduced growth rates, lower productivity, and higher mortality among animals lead to financial losses. These increased costs are often passed on to consumers in the form of higher prices for animal products. Thus, antibiotic resistance not only affects animal health but also has broader economic implications.

Public Health Implications: Antibiotic resistance in animals poses significant risks to human health. Resistant bacteria can be transmitted to humans through the consumption of contaminated food products, direct contact with animals, or exposure to contaminated environments. Individuals working in farms or veterinary settings are particularly vulnerable to acquiring resistant infections. This interconnection highlights the importance of addressing antibiotic resistance as a shared concern between animal and human health sectors.

Reduction in Effective Antibiotics: As antibiotic resistance increases, the number of effective drugs available for treatment decreases. Many older antibiotics have become ineffective, and newer alternatives are often more expensive and have a broader spectrum of activity. The use of antibiotics that are critical for human medicine in animals raises serious ethical concerns, as it may contribute to resistance that affects human healthcare.

Environmental Impact: Antibiotic residues and resistant bacteria enter soil and water through agricultural runoff and waste disposal. These contaminated environments act as reservoirs of resistance genes, which can spread among microorganisms and eventually reach animals and humans. This environmental dimension further complicates the control of antibiotic resistance.

7. Approaches to tackle Antibiotic Resistance in Animals

The containment of antibiotic resistance is an ongoing endeavor. Antimicrobial resistance impacts human, animal, and environmental health, hence "One Health" mitigation strategies including pertinent sectors are necessary (Collignon and McEwen, 2019). The



World Health Organization's (WHO) Global Action Plan lists several tactics that nations can employ to lessen the growing danger, such as "improving awareness and understanding of AMR through effective communication, education, and training" (WHA, 2015). The Food and Agriculture Organization of the United Nations (FAO), the World Organization for Animal Health (OIE), and the World Health Organization (WHO) are collaborating to support the creation of AR-related policies within the One Health framework in an effort to fight AR. These organizations have also established guidelines for AR surveillance to ensure comprehensive monitoring of antimicrobial usage and consumption across animal, human, and environmental settings.

To combat this issue, precautions and timely measures should be taken into consideration. These include: consulting your veterinarian frequently for the right medication and dosage; adhering to farm cleaning procedures and good husbandry practices; adhering to livestock welfare standards and protocols; avoiding giving animals overdoses or unprescribed drugs; giving veterinarian-recommended vaccinations to prevent diseases; separating sick animals immediately to prevent the spread of disease; and keeping an eye out for signs of illness. The creation of national and worldwide surveillance and monitoring programs for antimicrobial resistance can aid in addressing the problem.

7. Rules and Regulations to address Antibiotic Resistance

A five-year action plan to promote antimicrobial stewardship in veterinary settings was created in 2019 by the FDA's Center for Veterinary Medicine (CVM). While maintaining the availability of safe and effective antibiotics for use in both humans and animals, the 2019–2023 plan seeks to reduce or reverse resistance resulting from the use of antibiotics in animals. The OIE Standards, Guidelines, and Resolution on antimicrobial resistance and the use of antimicrobial agents were released by the OIE (World Organization for Animal Health).

As part of a larger strategy to address the public health risks associated with antibiotic use in food animal production and to strategically align with changing international trade requirements, the Indian government has taken significant regulatory steps to reduce the use of antibiotics in food-producing animals. Antimicrobial resistance (AMR) in food animals, especially poultry, is now tracked and compiled by the Indian Council of Agriculture Research (ICAR) in India. The data is regularly released in the Indian Network for Fisheries and Animal Antimicrobial Resistance (INFAAR) yearly report. The Central Drugs Standard Control Organization (CDSCO) of India's Drugs Technical Advisory Board (DTAB) is working with ease to outlaw the use of illogical antibiotics in food animals. In October 2024, the Food Safety and Standards Authority of India (FSSAI) prohibited the use of antibiotics at any stage of



production ranging from rearing to final processing in key food sectors such as milk, meat, poultry, eggs, aquaculture and particularly honey.

8. Positive Outcomes of Antibiotic Resistance

Antibiotic resistance has brought forth a number of beneficial advancements despite its negative effects. Better infection control procedures, the creation of alternate treatment approaches, and enhanced animal management systems have all been prompted by increased awareness of the issue. For instance, more sustainable methods have been made possible by the use of topical treatments, improved hygiene, and a decreased reliance on antibiotics for growth stimulation. These modifications demonstrate the possibility of adjusting to the difficulties brought on by antibiotic resistance.

9. Conclusion

A diversified strategy is needed to combat antibiotic resistance. Antibiotics must be used rationally, that is, only when necessary and in the right dosages. To integrate efforts across the human, animal, and environmental sectors, the One Health strategy must be put into practice. The spread of infections can be stopped by improved biosecurity and hygiene practices. To limit the use of antibiotics and encourage monitoring and surveillance, strict laws and regulations are required. Antibiotic use can also be decreased by preventive measures like immunization, healthy diet, and improved animal housing.

10. Future Perspective

In the future, the development of new antibiotics for veterinary use is expected to be limited. Therefore, greater emphasis must be placed on prevention rather than treatment. Global cooperation and combined strategies, increased awareness, and responsible practices will be essential in managing antibiotic resistance. Maintaining animal health through improved management strategies will play a key role in reducing reliance on antibiotics.

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