BRIDGING THE GAP IN AMR: INTEGRATIVE CONTROL MEASURES FOR ANTIBIOTIC RESISTANCE IN HUMAN, ANIMAL AND ENVIRONMENTAL HEALTH

Cosmin ȘONEA[1], Dana TĂPĂLOAGĂ [1], Lucian ILIE[1], Cristinel Gigi ȘONEA[2], Raluca-Aniela GHEORGHE-IRIMIA[1#], Elena-Nicoleta STANCIU[1], Paul-Rodian TĂPĂLOAGĂ[1]

[1] University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, District 1, Bucharest, Romania
[2] Ministry of Agriculture and Rural Development, Bucharest, Romania

REVIEW

Abstract
Antimicrobial resistance (AMR) represents a significant global health threat, driven by the improper use of antibiotics in human healthcare, veterinary medicine, and environmental systems. This review consolidates current evidence on the diverse factors contributing to AMR, emphasizing the interconnected nature of human, animal, and environmental health within the framework of the One Health approach. Proposed solutions to address AMR include prudent antibiotic usage, robust waste management strategies, the advancement of vaccines and alternative therapies, and widespread educational initiatives targeting both healthcare professionals and the general public. Furthermore, the review highlights the critical role of international collaboration in data sharing and the development of regulatory frameworks to monitor and control AMR effectively. By targeting the underlying drivers of resistance and implementing integrated strategies, stakeholders can collectively reduce the impact of resistant pathogens and protect global health. Special attention is needed in low- and middle-income countries, where the AMR problem is disproportionately high, underscoring the importance of equitable and coordinated action.

Keywords: Antimicrobial Resistance, One Health, antibiotics

[#]Corresponding author: raluca.irimia@fmv.usamv.ro

INTRODUCTION

Antimicrobial resistance (AMR) represents an escalating global health challenge, fuelled by the ability of microorganisms to withstand the antimicrobials that were once effective. The widespread and often inappropriate use of antimicrobial agents in clinical and agricultural settings has intensified this challenge, leading to infections that are becoming increasingly difficult to manage. Identified by the World Health Organisation (WHO) as one of the leading global public health threats, AMR could lead to an estimated 10 million deaths each year by 2050 if existing trends continue (Godinho, 2024). In addition to affecting personal health, AMR presents considerable challenges for healthcare systems, economies, and ecosystems (Vikesland et al., 2019; Ferri et al., 2015).

The intricacies of AMR arise from various elements, such as overprescription of antibiotics, inappropriate use in agriculture, and insufficient infection control measures. (Abbo & Hooton, 2014, Brown et al., 2016; Saini et al., 2012). To tackle these challenges, it is essential to adopt a "One Health" approach that highlights the interrelation of human, animal, and environmental health (Matar et al., 2020).

The interconnected dynamics of AMR highlight the importance of understanding its transmission pathways and impacts. In agricultural contexts, antibiotic use not only fosters resistance in bacteria affecting livestock but also contaminates the environment, introducing resistant strains into ecosystems. These bacteria can enter the food supply and infect humans, complicating treatment efforts (Brown et al., 2016; Saini et al., 2012, Wang et al., 2023, Godinho, 2024; Wang et al., 2023, Vikesland et al., 2019; Wang et al., 2023).

Socioeconomic factors significantly influence the prevalence and control of AMR. In numerous low- and middle-income nations, the accessibility of over-the-counter antibiotics alongside insufficient healthcare infrastructure leads to misuse (Ayukekbong et al., 2017). The lack of awareness among healthcare providers and the general public about AMR poses significant challenges to prevention and stewardship initiatives (Waseem et al., 2019; Abera et al., 2014; Kraker et al., 2011; Kraker et al., 2011; Waseem et al., 2019; Ferri et al., 2015).

The aim of this review is to explore the multifaceted drivers and impacts of AMR across human, animal, and environmental sectors, emphasizing the interconnected nature of the problem.

AMR ACROSS SECTORS

The misuse of antibiotics in healthcare drives AMR. These vital medications are misused due to overprescription, patient demand, and poor diagnostic tools. Studies show that many antibiotics are useless, especially for viral illnesses when they have no therapeutic benefit (Smit, 2023). Misuse fails to treat infections and selectively pressures bacterial populations, promoting resistance.

Lack of timely diagnostic tools worsens the issue. Empirical prescribing without bacterial illness typically leads to needless broad-spectrum antibiotic use, which increases resistance (Sjöström et al., 2020). Lack of information among healthcare providers regarding AMR's long-term effects perpetuates overuse and poor management (Waseem et al., 2019; Abera et al., 2014).

The clinical effects of AMR are significant. Resistant infections like MRSA and ESBL-producing Escherichia coli require sophisticated and expensive treatments with less effective or more hazardous alternatives (Kraker et al., 2011). AMR affects 33,000 Europeans annually, causing major economic and healthcare costs (Davies & Wales, 2019, Kasimanickam et al., 2021).

In many regions, antibiotics are administered not only to treat infections but also for growth promotion and disease prevention in healthy animals. These practices create selection pressure, encouraging the proliferation of resistant bacteria (Mshana et al., 2021; Tiseo et al., 2020).

Inadequate veterinary oversight and the indiscriminate use of antimicrobials exacerbate the problem. Resistant strains originating in animals can be transmitted to humans through direct contact, consumption of contaminated meat products, or environmental exposure (Smith et al., 2023; Rhouma et al., 2022). Moreover, antibiotic use in companion animals is a growing concern, as misuse by pet owners contributes to resistance in pathogens that can cross the human-animal interface (Delalay et al., 2020).

The environmental impact of antibiotic use in agriculture is also significant. Resistant bacteria from livestock waste can contaminate soil and water systems, creating hotspots for resistance development (Nhung et al., 2015; Holvoet et al., 2013). Intensive farming practices with poor biosecurity measures further amplify the problem, necessitating stricter regulations and surveillance systems (Amin et al., 2020; Rhouma et al., 2022; Șonea, 2023a; Șonea, 2023b; Gheorghe-Irimia, 2023).

Agricultural runoff, hospital wastewater, and untreated sewage introduce resistant bacteria into natural ecosystems, where they persist and propagate (Holvoet et al., 2013; Guenther et al., 2011). Water systems, in particular, play a critical role in AMR dissemination. Contaminated water bodies not only affect aquatic ecosystems but also pose significant risks to human populations that rely on them for drinking and irrigation (Holvoet et al., 2013).

Soil contamination is another critical pathway. The application of manure from treated livestock can introduce resistant bacteria into agricultural soils, facilitating horizontal gene transfer and further resistance development within microbial communities (Nhung et al., 2015; Guenther et al., 2011). These bacteria can then affect crops, which may serve as another vector for AMR transmission to humans.

STRATEGIES FOR ANTIMICROBIAL RESISTANCE (AMR) REDUCTION

A critical strategy in combating AMR is ensuring antibiotics are used responsibly and only when necessary. This involves selecting the appropriate drug tailored to the specific infection. Evidence demonstrates that antimicrobial stewardship interventions, such as educational campaigns and clinical guidelines, can significantly improve antibiotic prescribing practices (Durkin et al., 2018; Gerber et al., 2013). For example, simple measures like displaying informational posters in outpatient clinics have successfully reduced inappropriate prescriptions for conditions like acute respiratory tract infections (Durkin et al., 2018).

Additionally, adopting a "wait-and-see" approach, where antibiotics are delayed unless clinically warranted, has been shown to lower unnecessary antibiotic use while encouraging patients to understand their appropriate application (Liu et al., 2019). Establishing stringent prescribing guidelines across healthcare and veterinary sectors is essential. In healthcare, implementing protocols that include regular audits and feedback mechanisms can help ensure adherence to evidence-based prescribing practices (Bello et al., 2021; Alkhuzaei et al., 2018). In veterinary medicine, regulations should restrict antibiotic use to prescription by licensed veterinarians and prohibit their application as growth promoters in livestock (Wilkinson et al., 2018).

Educational campaigns targeting both healthcare providers and the public are vital in fostering responsible antibiotic use. Research indicates that such interventions can significantly reduce antibiotic consumption (Velden et al., 2013; Zetts et al., 2020). For example, public awareness initiatives can inform individuals about the dangers of antibiotic misuse, while healthcare providers benefit from continuous training on stewardship principles, including appropriate prescribing and the use of diagnostic tools.

For healthcare professionals and farmers, tailored training programs are crucial. Healthcare providers should receive ongoing education on stewardship practices, while farmers should be trained in responsible antibiotic use under veterinary supervision. Collaborative initiatives that bring together these stakeholders can advance the One Health approach to addressing AMR (Watkins et al., 2019; Alkhuzaei et al., 2018).

Effective prevention of antimicrobial resistance (AMR) dissemination via environmental pathways necessitates the implementation of comprehensive waste management systems across healthcare, agricultural, and industrial sectors. Hospitals have effectively reduced environmental contamination by adopting engineering controls, including closed-system transfer devices (CSTDs) (Sessink, 2024). In agriculture, effective management of waste products, including composting and anaerobic digestion, can reduce the effects of antibiotic residues on soil and water systems (Watkins et al., 2019; Sessink, 2024).

Vaccination is essential for infection prevention and decreasing dependence on antibiotics. Vaccination against bacterial diseases can markedly reduce the occurrence of infections necessitating antibiotic intervention. Investment in vaccine research is essential, especially for diseases lacking effective vaccines (Alanazi, 2023).

Vaccines in agriculture can effectively prevent diseases in livestock, thereby reducing the reliance on antibiotics. Alternative therapies, including probiotics, bacteriophage therapy, and herbal remedies, demonstrate potential in preventing or treating infections and mitigating the risk of resistance development (Alanazi, 2023; Tudor, 2023). Investigation into these alternatives should emphasise their effectiveness in both human and veterinary medicine.

Countries must share surveillance data, best practices, and strategies for antibiotic regulation and resistance management. International organizations, such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), provide critical frameworks for addressing AMR, offering resources to standardize interventions worldwide (Alanazi, 2023; Gerber et al., 2013).

Collaboration is particularly crucial for addressing socioeconomic disparities in low- and middle-income countries, where the AMR burden is often highest. Strengthening global research efforts to develop new antibiotics and alternatives, coupled with monitoring and regulating antibiotic use, is essential for mitigating the impact of AMR on public health systems (Alanazi, 2023; Gerber et al., 2013).

CONCLUSIONS

Antimicrobial resistance (AMR) represents a complex global health challenge that demands urgent, collaborative, and thorough intervention. To tackle this challenge, it is essential to combine efforts across human, animal, and environmental health using a holistic approach. Essential strategies, including careful antibiotic administration, effective waste management, vaccination efforts, and the creation of alternative therapies, should be integrated with educational initiatives to enhance awareness and encourage behavioural transformation. Moreover, international cooperation is crucial for developing regulatory frameworks, exchanging surveillance data, and assisting low- and middle-income countries that are disproportionately impacted by AMR. Through the application of these strategies, stakeholders can reduce the effects of AMR, protect the effectiveness of antimicrobials, and secure sustainable public health results for future generations.

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