Short Communication

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Bacterial resistance: a growing challenge and strategies in public health and one health

Summary

Bacterial resistance is a phenomenon caused by the evolution of microorganisms, which develop defense mechanisms against antimicrobials, making treatment of infections more difficult. The inappropriate and excessive use of antibiotics, combined with self-medication, poor control in the production chain, and poor sanitary conditions, accelerates the emergence of resistant strains, especially in hospital settings, where bacteria such as *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* pose challenges. This resistance increases hospitalization time, costs, and mortality, acting through mechanisms such as β- lactamases, mutations, and efflux pumps. To combat this problem, strategies such as the use of artificial intelligence in the research of new antimicrobials, rational use policies, surveillance, hygiene, and public education are essential. International cooperation, multidisciplinary actions, and evidence-based policies are essential to preserve the effectiveness of antimicrobials and protect global health. This article reviews the main contributing factors, clinical impacts, and strategies needed to mitigate this emerging problem.

Keywords: antimicrobials, epidemiological control, infections, one health, public health

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Introduction

Bacterial resistance occurs when microorganisms evolve defense mechanisms against antimicrobial agents, making treatment of infections difficult or impossible. Since the discovery of the first antibiotics, the indiscriminate and inappropriate use of these drugs has accelerated the development of resistant strains, becoming one of the greatest threats to contemporary public health.[1]

Bacterial resistance represents one of the greatest current challenges in public health, hindering the successful treatment of common infections and increasing global mortality. According to the World Health Organization (WHO), antimicrobial resistance threatens to reverse decades of medical advances, turning previously treatable infections into life-threatening infections.[2] Factors such as the inappropriate use of antibiotics in human medicine, agriculture, and animal husbandry significantly contribute to the development and spread of resistant bacteria. Furthermore, the lack of new antimicrobials on the market further complicates the situation, demanding global surveillance strategies and rational use of these drugs.

Recent studies highlight that bacterial resistance is rapidly expanding, especially in hospital settings, where infections by multidrug- resistant bacteria such as *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* pose a growing threat.[3] Implementing infection control measures, along with promoting the rational use of antimicrobials, is essential to curb this trend. Research also points to the importance of innovation in the search for new drugs and therapeutic alternatives, including the use of bacteriophages and combination therapies, as promising strategies to address bacterial resistance in the near future.[4]

Methodology

To identify and analyze the challenges and effective approaches related to AMR, covering resistance mechanisms, the impact of inappropriate antibiotic use, hospital-acquired infections, environmental factors, and control strategies, we followed defined systematic procedures. The review included articles published between 2010 and 2025 to ensure the relevance and timeliness of the data. Studies, systematic reviews, and academic articles addressing antimicrobial resistance mechanisms, control strategies, and the impacts of antibiotic use were considered.

The following databases and sources were used: PubMed, Google Scholar, Scopus, the World Health Organization (WHO) database with global reports and guidelines on antimicrobial resistance; and university libraries to consult relevant academic books and institutional reports, using the following search terms: “hospital infections”, “antimicrobial resistance”, “resistance mechanisms”, “inappropriate use of antibiotics”, “infection control” and “development of new antibiotics”.

Results and discussions

Contributing factors

Several factors contribute to the rise of bacterial resistance, including the excessive and incorrect use of antibiotics in human and veterinary medicine, self-medication, lack of control in the production and distribution chain, and issues related to poor hygiene and sanitation.[5] We can also mention target modifications in antibiotic structures, such as alterations in ribosomes that reduce the effectiveness of tetracyclines,[6] and modifications that degrade antibiotics, such as beta- lactamases[7] and efflux pumps. This global mobility also favors the spread of resistant strains, hindering epidemiological control.[8]

Clinical and epidemiological impacts

Bacterial resistance increases hospital stays, raises treatment costs, and increases mortality from previously manageable infections. Infections caused by multidrug-resistant bacteria, such as methicillin-resistant *Staphylococcus aureus (MRSA) and Klebsiella pneumoniae* and resistant *Mycobacterium tuberculosis*, pose significant clinical challenges.[5] Furthermore, the shortage of new antimicrobials further aggravates the situation.

The excessive, indiscriminate and inappropriate use of antibiotics is considered a critical factor in resistance, according to Ventola[9] Other researchers[10] warn that self-medication and lack of control in pharmaceutical units increase selective pressure on the microorganisms in question, facilitating and increasing this resistance.

Antimicrobial resistance (AMR) has become one of the greatest threats to global public health, compromising the effectiveness of conventional treatments and increasing mortality from previously controllable infections. Resistance mechanisms can be classified into several categories, including the production of enzymes that inactivate antimicrobials, changes in bacterial membrane permeability, modification of the antibiotic's target, and activation of efflux pumps that expel the drug from the cell.[11] For example, β-lactamases, enzymes produced by bacteria such as *Escherichia coli* and *Klebsiella pneumoniae* , degrade β-lactam antibiotics, rendering them ineffective[12] and observations associated with multidrug resistance promoting permeability in membrane alterations preventing the entry of antibiotics, as observed in *Pseudomonas aeruginosa*.[13] Furthermore, genetic mutations can lead to alterations in the binding sites of the antibiotic to its target, as occurs in quinolone resistance, where mutations in gyrase and topoisomerase IV reduce the affinity of the drug.[14]

Another important mechanism is target modification, which prevents the antimicrobial from binding to its specific structure. A classic example is aminoglycoside resistance, where amino acid modifications in target proteins prevent drug binding, reducing its effectiveness.[15] Furthermore, efflux pumps, which are active transport systems present in the bacterial membrane, play a crucial role in resistance, expelling various types of antibiotics and hindering drug concentration in the cell.[16] These mechanisms often act together, conferring multifactorial resistance on bacteria that complicates clinical treatment. Therefore, understanding these processes is crucial for developing new therapeutic strategies and control policies that can mitigate the spread of AMR.[4]

Coping strategies

Artificial intelligence (AI) has played a key role in addressing antimicrobial resistance (AMR), a growing threat to global health. One of the most promising applications of AI in this context is molecular discrimination, which involves analyzing the chemical and genomic structures of antibacterial agents and pathogens. Using machine learning algorithms, researchers can identify molecular patterns and characteristics that contribute to the efficacy or resistance of certain compounds, facilitating the selection of promising candidates for the development of new antibacterials.[17] Furthermore, AI-based computational modeling allows for the simulation of interactions between drugs and bacteria, accelerating the process of discovering effective agents and reducing costs and time compared to traditional methods.[18] These innovative approaches enhance the identification of molecules with high affinity for bacterial targets, contributing to the development of more effective therapies against resistant strains.[19] Thus, the integration of AI into antibacterial research represents a crucial strategy to overcome the obstacles imposed by AMR, enabling the development of more precise and effective agents.

Antimicrobial resistance (AMR) is now recognized as a global public health threat that requires a collaborative and integrative approach known as One Health. When microorganisms such as bacteria, fungi, viruses, and parasites become resistant to available antimicrobial drugs (antibiotics, antifungals, antivirals, antimalarials, or anthelmintics), they become difficult-to-treat infectious agents and increase the risk of transmission,[20] One Health enters this stage by confirming the interconnection between human, animal, and environmental health, seeking more accurate and collaborative solutions to resolve and resolve health problems caused by vectors and infectious agents that are harmful to public health.

Implementing policies for the rational use of antimicrobials, strengthening epidemiological and laboratory surveillance, promoting hygiene and sanitation practices, and investing in research and development of new drugs are essential actions to curb the spread of resistance.[1] Educating the public and health professionals also plays a fundamental role in reducing the misuse of antibiotics.

Conclusion

Bacterial resistance represents one of the greatest public health challenges facing us today, due to its complexity and the multiple variables involved. This issue requires a multidisciplinary and integrated approach, involving not only healthcare professionals, but also researchers, policymakers, the scientific community, and society at large. International cooperation is crucial in this context, as antimicrobial resistance does not respect geographic borders, and the circulation of resistant bacteria can occur rapidly and globally. Furthermore, the implementation of effective public policies based on scientific evidence is essential to regulate the rational use of antimicrobials, prevent their indiscriminate use, and promote control and prevention strategies. Social awareness also plays a crucial role, as it is necessary to educate the population about the importance of responsible medication use, proper hygiene, and preventive measures to reduce the spread of resistant infections. Only through coordinated, continuous, and responsible action across all these aspects will it be possible to guarantee the effectiveness of antimicrobials, preserve global health, and prevent bacterial resistance from continuing to threaten medical advances and the quality of life of populations around the world. In summary, antimicrobial resistance is a serious, relevant, and concrete threat that spans multiple sectors in human, animal, and environmental health, and the One Health approach is essential for intervention and combat against these infections. By considering the interconnection between human, animal, and environmental health, One Health enables the development of effective and sustainable strategies to protect the health of all living beings, avoiding emergency disruptions.

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Conflicts of interest

The author declares there is no conflict of interest.

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