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NARRATIVE REVIEW

Can Indiscriminate Use of Antibiotics Act as a Key Driver of Antimicrobial Resistance?

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Abstract

Antimicrobial resistance (AMR) has emerged as a major global public health threat, compromising the effective treatment of infectious diseases caused by a variety of organisms. The widespread and uncontrolled use of antibiotics in human healthcare, veterinary medicine, and agriculture is a main contributor to this problem. Practices, such as improper prescribing, self-medication, and routine use in food-producing animals exert selective pressure that encourages the development and spread of resistant microorganisms. These resistant pathogens lead to treatment failures, increased morbidity and mortality, and higher healthcare costs. It is estimated that about one million people die from AMR infections every year in the world. This article highlights the role of irrational antibiotic use in the development of AMR and emphasizes the need for responsible antibiotic stewardship. Judicious use of antibiotics in clinical practice is essential. Strengthening regulatory frameworks, improving public awareness, and adopting a One Health approach are essential to curb the growing threat of antimicrobial resistance.

Keywords: antibiotics; antimicrobial resistance; one health; public health.

1. Introduction

The uncontrolled and inappropriate use of antibiotics in both developing and developed countries has resulted in antimicrobial resistance (AMR). Antimicrobial resistance is considered as one of the most pressing public health challenges of the 21st century [1]. Antibiotic resistance poses significant threats to public health, global economies, and food security [1]. It is mentioned that AMR infections are responsible for approximately one million deaths annually worldwide [2]. The misuse and overuse of antimicrobials across human, animal, and plant sectors are recognized as the main drivers of antimicrobial resistance [3]. AMR occurs when microorganisms such as bacteria, viruses, fungi, or parasites evolve to resist the effects of drugs designed to eliminate them, rendering standard treatments ineffective [4]. Among all forms of AMR, antibiotic resistance in bacteria poses the greatest threat because antibiotics are foundational to modern medical practice, underpinning surgeries, cancer chemotherapy,

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organ transplantation, and treatment of infectious diseases [5]. A central and widely accepted driver of AMR is the indiscriminate use of antibiotics, which refers to their inappropriate prescription, unnecessary consumption, and extensive use in agriculture and animal husbandry. This article explores how indiscriminate antibiotic use drives AMR, examines the mechanisms behind resistance development, and discusses global consequences, contributing factors, and preventive strategies.

2. Antibiotics and Their Purpose

Antibiotics are agents that kill or inhibit bacterial growth [1]. Since the discovery of penicillin in 1928, antibiotics revolutionized medicine and saved countless lives. These drugs are crucial in treating bacterial infections such as pneumonia, tuberculosis, sepsis, and wound infections [6]. Ideally, antibiotics should be prescribed when bacterial infection is confirmed or highly suspected, and when the benefits outweigh the risks. However, in practice, antibiotics are often used without medical justification.

3. What Constitutes Indiscriminate Antibiotic Use?

Indiscriminate antibiotic use encompasses several behaviours:

- Overprescription by healthcare providers for viral illnesses, such as the common cold or flu, against which antibiotics are ineffective [7].
- Self-medication with leftover antibiotics or drugs purchased without a prescription.
- Use of broad-spectrum antibiotics when narrow-spectrum drugs would be appropriate.
- Sub-therapeutic and routine use in animal farming, including as growth promoters and prophylactics [8].
- Environmental and pharmaceutical sources of antibiotic use lead to environmental contamination (hospital effluents, sewage, pharmaceutical waste and industrial discharge) and in spreading antibiotic residues and resistant genes [9].
- Wastewater treatment plants act as AMR hotspots for horizontal gene transfer [10].

These practices increase antibiotic exposure in humans and animals, producing selection pressure that accelerates the emergence of resistant microbes.

4. Mechanisms Behind Resistance Development

Bacteria have innate capacities to adapt genetically. Antibiotic exposure, especially when inappropriate, selects for bacterial strains with resistance genes. Key mechanisms include:

- **Mutation:** Random genetic mutations can change bacterial proteins targeted by antibiotics, making the drug ineffective.
- **Gene transfer:** Bacteria can share resistance genes via plasmids, transposons, or bacteriophages through horizontal gene transfer, spreading resistance across species [11].

- **Role of biofilms and subtherapeutic exposure:** Biofilms shield bacteria from antibiotics, while sub-therapeutic drug exposure promotes survival, adaptation, and horizontal gene transfer, accelerating antimicrobial resistance and causing persistent, difficult-to-treat infections [12], [13].

For example, indiscriminate antibiotic use can encourage bacteria to produce enzymes such as β-lactamases, which deactivate β-lactam antibiotics like penicillins and cephalosporins. Similarly, efflux pumps may develop to expel antibiotics from bacterial cells before they exert an effect [14]. Once resistance traits emerge, resistant bacteria multiply and propagate, even in the absence of antibiotics, complicating future treatment.

5. Clinical and Public Health Consequences

The consequences of antibiotic resistance driven by indiscriminate use are grave and multifaceted:

- **Treatment failure:** Standard antibiotics become ineffective, leading to prolonged illness and increased risk of complications.
- **Increased mortality:** Resistant infections are associated with higher death rates. For example, drug-resistant tuberculosis and methicillin-resistant *Staphylococcus aureus* (MRSA) infections have significantly higher mortality than drug-sensitive forms [15].
- **Higher healthcare costs:** Resistant infections often require more expensive drugs, longer hospital stays, and additional supportive care.
- **Threat to medical procedures:** Many medical procedures, including surgeries and chemotherapy, rely on effective antibiotics to prevent and treat infection risk [16].
- **Economic and health care system burden of AMR:** Increased hospitalization costs, productivity loss and burden on national health budgets [17].

6. Factors Promoting Indiscriminate Use

Several interrelated factors drive indiscriminate antibiotic consumption:

- **Inadequate prescribing practices:** Healthcare providers may prescribe antibiotics without definitive evidence of bacterial infection due to diagnostic uncertainty, patient demand, fear of complications, or lack of adherence to guidelines [18]. In many low- and middle-income countries, antibiotic stewardship programs that regulate proper antibiotic prescribing are weak or absent.
- **Easy access and self-medication:** In many regions, antibiotics are available over the counter without a prescription, facilitating self-medication. Patients with limited access to professional healthcare may treat symptoms with antibiotics inappropriately, contributing to resistance pressure.
- **Agricultural use:** Antibiotic use in livestock and aquaculture is extensive. Antibiotics are used therapeutically, prophylactically, and as growth enhancers in healthy animals. This practice creates a reservoir of resistant bacteria in animals that can transfer to humans via food, environment, and direct contact [8].

- **Veterinary and zoonotic dimensions of AMR:** Transmission of zoonotic bacteria from animals to humans and food chain and environmental spread [19]. Antimicrobial use in food-producing animals promotes resistant bacteria that can transmit to humans through the food chain, direct contact, and the environment. Zoonotic pathogens increasingly exhibit resistance, emphasizing the need for prudent veterinary antibiotic use within a One Health framework [8].
- **Lack of awareness and education:** Many patients believe antibiotics are a cure-all for infections, including viral illnesses, and may pressure clinicians for prescriptions. Lack of awareness about AMR and its consequences contributes to misuse.
- **Poor quality, counterfeit, and substandard antibiotics:** Substandard and counterfeit antibiotics deliver inadequate drug concentrations, promoting sub-therapeutic exposure, treatment failure, and rapid selection of resistant pathogens, particularly in regions with weak regulation and informal drug markets [20].
- **Behavioural, cultural, and societal drivers:** Patient demand, misconceptions that antibiotics cure all infections, self-medication, informal healthcare practices, and poor adherence to prescriptions drive inappropriate antibiotic use, sustaining selective pressure and accelerating antimicrobial resistance despite existing guidelines and awareness efforts [21].

7. Global Dimensions of the Problem

Antimicrobial resistance is a worldwide issue transcending national borders. Resistant bacteria spread through travel, trade, environmental contamination, and animal migration. The World Health Organization (WHO) estimates that by 2050, AMR could contribute to 10 million deaths annually, surpassing deaths from cancer if current trends continue [22]. Countries with weak health systems and uncontrolled antibiotic markets face disproportionate risks of accelerated AMR. Climate change influences antimicrobial resistance by altering ecosystems through rising temperatures, flooding, and extreme weather events. These changes enhance bacterial survival, transmission, and horizontal gene transfer, facilitating the environmental persistence and global dissemination of resistant pathogens across human, animal, and ecological interfaces [23].

8. Strategies to Mitigate Indiscriminate Use and Resistance

Addressing AMR requires a comprehensive, multisectoral response under the One Health framework, recognizing the interconnectedness of human, animal, and environmental health. Key strategies include:

- **Strengthening antibiotic stewardship:** Antibiotic stewardship programs aim to optimize antibiotic use by enforcing evidence-based prescribing, monitoring antibiotic consumption, and educating clinicians and patients about appropriate use [24]. Stewardship programs have been shown to reduce unnecessary prescriptions and slow the emergence of resistance.

- **Regulation and policy enforcement:** Governments must enforce prescription-only policies for antibiotics and regulate antibiotic use in agriculture. Reducing routine use of antibiotics in livestock and aquaculture is crucial to limiting environmental and food-borne reservoirs of resistance.
- **Public education and awareness:** Community programs to educate patients about the dangers of antibiotic misuse and the importance of adherence to prescribed regimens can reduce self-medication. Public health campaigns have been effective in improving antibiotic use behaviours.
- **Surveillance and research:** Robust surveillance systems to track antibiotic use and resistance patterns are essential for informed policy decisions. Investment in research for new antibiotics, diagnostics, vaccines, and alternative therapies is critical to staying ahead of evolving resistance.
- **Environmental controls and waste management:** Effective environmental controls, including proper treatment of hospital effluents, pharmaceutical waste, and municipal wastewater, are essential to reduce antibiotic residues and resistant microorganisms. Strengthened waste management, regulatory enforcement, and monitoring of environmental reservoirs can significantly limit the environmental amplification and spread of antimicrobial resistance [25].
- **Emerging alternatives to antibiotics:** To combat antimicrobial resistance, several alternatives to conventional antibiotics are under development, including bacteriophage therapy, antimicrobial peptides, CRISPR-based antimicrobials, vaccines, probiotics, and microbiome-modulating strategies. These approaches reduce reliance on antibiotics by targeting pathogens more specifically or enhancing host immunity, thereby limiting selective pressure and slowing resistance emergence. Continued research and clinical validation are essential for their widespread adoption [26], [5].

9. Ethical and Legal Considerations in Antibiotic Use

Antibiotics are a shared global resource, and their effectiveness must be protected for both present and future generations. When antibiotics are used carelessly, antimicrobial resistance rises, putting everyone at risk and reducing treatment options for the future. This is not just a medical issue but an ethical one, as today's misuse directly harms the health of generations to come. From a legal perspective, governments have a responsibility to regulate antibiotic access, limit over-the-counter sales, monitor use in agriculture, and enforce stewardship through surveillance and accountability. At the same time, clinicians, veterinarians, pharmaceutical companies, and consumers all share a moral duty to use antibiotics responsibly. Recognizing antibiotics as a limited common good calls for ethical prescribing, strong regulation, and global cooperation to protect public health across borders, sectors, and ecosystems [27].

10. Conclusion

Despite advances in the scientific field, antimicrobial resistance remains a major challenge to public health organizations. Indiscriminate use of antibiotics is the main driver of antimicrobial resistance, significantly undermining the effectiveness of modern medicine. The overprescription of antibiotics, self-medication,

inappropriate agricultural use, and lack of regulatory enforcement all contribute to the selection and spread of resistant pathogens. With AMR posing a threat to global health, economies, and food systems, urgent action is needed. Strengthening antibiotic stewardship, improving regulation, promoting public awareness, and fostering global cooperation are indispensable components of the response. The fight against AMR requires sustained political commitment, cross-sectoral interventions, and informed engagement by healthcare providers, policymakers, industry, and communities alike.

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