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Antibiotic Resistance: A Critical Global Health Concern -Causes, Mechanisms, and Solutions

Syed Ahefaz Ali Qamar Ali, Kavita Bisendra Mishra, Runali Dilip Bhumbar, Shrihali Pradip Hedau, Prachi Kishor Lambat, Soniya Prithvi singh Rajput, Vivek Prabhakar Ghagare.

Priya Darshini J.L College of Pharmacy Electronic Zone Building, MIDC, Hingna Road, Nagpur 440016

Abstract

Among the most serious challenges to current medicine and worldwide public health is antibiotic resistance (AR). Development of resistant bacterial strains has been speeded up by human and animal misuse and overuse of antibiotics, hence reducing the effectiveness of treatment. Highlights the present worldwide and particularly in India, discusses challenges in controlling resistance, and provides techniques and new treatments to fight against this crisis, this review investigates the main causes and molecular mechanisms underlying antibiotic resistance. Preserving antibiotic efficacy for next generations depends on a multi-disciplinary approach combining public awareness, innovation, and stewardship.

Keywords : Antibiotic resistance, Antimicrobial stewardship, MDR bacteria, Drug-resistant infections, Public health, India, Mechanisms of resistance, Overuse of antibiotics, AMR, Bacteriophage therapy, Rapid diagnostics, Global health crisis.

Introduction

Starting with penicillin in 1928, the finding of antibiotics changed bacterial infection treatment and greatly lowered worldwide death rates. Rising resistant bacteria, however, are progressively eroding the potency of antibiotics. When germs develop means of surviving exposure to medications developed to kill or slow them, antibiotic resistance arises. The World Health Organization (WHO) has designated antimicrobial resistance a worldwide health emergency, cautioning that it risks reversing many years of medical advances[1-3].

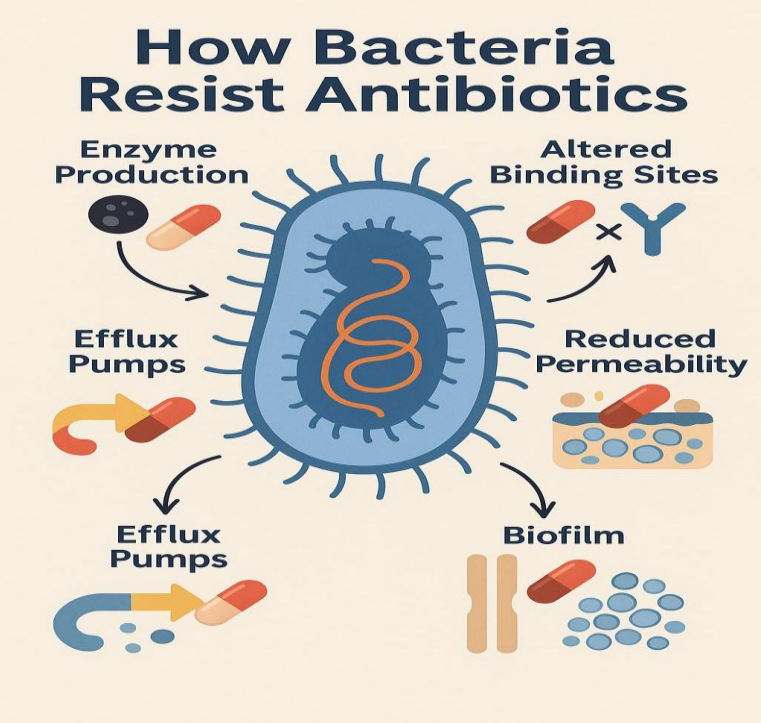
Reasons behind Antibiotic Resistance

The abuse and overuse of antibiotics in human medicine and agriculture mostly propel the growth of antibiotic resistance. Particularly in low and middle income nations like India[5], self-medication, non-prescription sales of antibiotics, and lack of regulatory control worsen the situation. Antibiotics are frequently prescribed needlessly for viral illnesses or administered at incorrect dosages and durations, therefore promoting resistance[4]. Moreover, antibiotics employed as growth promoters and preventives in livestock production help resistant genes pass from animals to humans via the food chain and the environment[6-7].

Mechanisms of Antibiotic Resistance in Bacteria

Bacteria evade antibiotics in several of means, including:

- Enzymatic breakdown or change: Formation of enzymes like beta-lactamases, which hydrolyze beta-lactam antibiotics, rendering them ineffective[8].
- Changes or mutations in the antibiotic's binding sites reduce medication affinity, such as alterations in penicillin-binding proteins[9].
- Active transport systems that push antibiotics out of bacterial cells, hence lowering the intracellular concentration of the drug, are known as efflux pumps[10].
- Less permeability: Modifications to membrane porins prevent antibiotics from entering cells[11].
- Biofilm formation: The formation of thick bacterial colonies inside a protective extracellular matrix limits antibiotic penetration and raises resistance[12].
- Encoded on mobile genetic elements like plasmids and transposons, these mechanisms would facilitate the fast distribution of resistance throughout bacterial populations[13]



Indian and Worldwide Environmental Resistance to Antibiotics

Significant healthcare problems worldwide are drug-resistant infections like methicillin-resistant Staphylococcus aureus (MRSA), multidrug-resistant tuberculosis (MDR-TB), and carbapenemresistantEnterobacteriaceae(CRE). India is seeing rising levels of resistance as a result of its high infectious disease load and difficulties in its healthcare system[14]. According to studies, clinical isolates from all over the nation have a high prevalence of extended-spectrum beta-lactamase (ESBL) producing E. coli and Klebsiella pneumoniae strains[15]. These resistant pathogens make therapy regimens more complicated and raise healthcare expenses, morbidity, and death rates[16].

Difficulties in the Battle against Antibiotic Resistance

Several difficulties impede the efficient control of antibiotic resistance:

- The development pipeline for antibiotics has shrunk as a result of technological challenges and low financial incentive for pharmaceutical companies[17].
- Due to slow or absent quick diagnostics, the use of empirical broad-spectrum antibiotics promotes resistance[18].
- Insufficient knowledge: Insufficient instruction for medical professionals and the general public on the topic of responsible antibiotic use impedes sensible antibiotic use[19].
- Gaps in enforcement and regulation: The widespread use of over-the-counter antibiotics without a prescription in many countries helps to abuse[20].

Strategies to fight Antibiotic Resistance

Fighting antibiotic resistance calls for a mix of approaches:

- Antimicrobial Stewardship Programs (ASPs): These programs guarantee that the correct medicine, dosage, and course of therapy are used, hence reducing unnecessary use and so improving antibiotic prescription techniques[21].
- Public education campaigns can help reduce overuse by raising awareness of antibiotic resistance and the need of completing prescribed courses[22].
- Pharmacists are easily accessible medical professionals who may instruct patients and oversee antibiotic administration[23].
- Knowing how human, animal, and environmental health interact makes possible coordinated efforts aimed at lowering resistance transmission[24].
- Targeted therapy benefits from the development and use of rapid diagnostic tests[25].
- Regulatory compliance: Rules restricting over-the-counter sales and promoting careful agricultural use are essential[26].

New Therapeutic Methods

Creative approaches help to fight resistant infections in addition to conventional antibiotics:

- Using viruses that selectively targets bacteria and maybe customized to resistant strains, bacteriophage treatment is possible[27].
- Alternative medicines are provided by natural or synthetic peptides with wide-spectrum antimicrobial activity known as antimicrobial peptides (AMPs).[28]
- Modulators of the microbiome and probiotics can improve host immunity and competitively suppress pathogenic bacteria[29].
- In drug discovery, artificial intelligence (AI) speeds up the finding of new antibiotic possibilities and assists in the fine-tuning of drug regimens[30].
- Vaccination: Avoiding bacterial infections lowers demand for antibiotics and so restricts resistance evolution[31].

Conclusion

A complicated, pressing danger requiring multi-pronged worldwide action is antibiotic resistance. It is possible to limit the spread of resistant pathogens via responsible antibiotic use, improved stewardship, diagnostic and therapeutic innovation, and coordinated health policies. Preserving the efficacy of antibiotics for current and future generations will depend critically on ongoing investment in research and education.

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