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ANTIBIOTIC RESISTANCE: A GLOBAL CHALLENGE OF MODERN MEDICINE

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Abstract. *Antimicrobial resistance (AMR) has become one of the most serious global public health threats of the twenty-first century. The increasing ability of pathogenic microorganisms to develop resistance against antibacterial agents significantly complicates the treatment of infectious diseases and contributes to increased morbidity, mortality, and healthcare expenditures worldwide.*

This review article analyzes the major mechanisms of antibiotic resistance, epidemiological trends, clinically significant resistant pathogens, and the impact of antimicrobial resistance on healthcare systems. Scientific publications indexed in PubMed, Scopus, Google Scholar, and WHO databases between 2020 and 2025 were reviewed using a narrative literature review approach. The findings demonstrate a global increase in multidrug-resistant organisms, including methicillin-resistant Staphylococcus aureus (MRSA), carbapenem-resistant Klebsiella pneumoniae, Pseudomonas aeruginosa, and Acinetobacter baumanni.

Irrational antibiotic prescribing, self-medication, excessive antibiotic use in agriculture, and insufficient infection-control measures remain the primary contributors to resistance development. The article emphasizes the importance of antimicrobial stewardship programs, early laboratory diagnostics, rational antibiotic use, and public health education in combating antimicrobial resistance. [3,5]

Keywords: *antimicrobial resistance, MRSA, beta-lactamase, carbapenem resistance, multidrug-resistant bacteria, antimicrobial stewardship, nosocomial infections. [3,5]*

АНТИБИОТИКОРЕЗИСТЕНТНОСТЬ: ГЛОБАЛЬНАЯ ПРОБЛЕМА СОВРЕМЕННОЙ МЕДИЦИНЫ

Аннотация. *Антимикробная резистентность является одной из наиболее серьезных глобальных проблем здравоохранения XXI века. Способность патогенных микроорганизмов вырабатывать устойчивость к антибактериальным препаратам значительно осложняет лечение инфекционных заболеваний и приводит к увеличению заболеваемости, смертности и экономических затрат системы здравоохранения. В данной обзорной статье анализируются основные механизмы антибиотикорезистентности, современные эпидемиологические тенденции, клинически значимые резистентные патогены и влияние антимикробной резистентности на систему здравоохранения.*

В ходе исследования были изучены научные публикации, индексированные в базах данных PubMed, Scopus, GoogleScholar и WHO в период 2020–2025 годов. Результаты показывают глобальный рост мультирезистентных микроорганизмов, включая MRSA, карбапенем-резистентную Klebsiellapneumoniae, Pseudomonasaeruginosa и Acinetobacterbaumannii. Основными факторами развития резистентности остаются нерациональное назначение антибиотиков, самолечение, чрезмерное применение антибиотиков в сельском хозяйстве и недостаточный инфекционный контроль. В статье подчеркивается важность программ рационального применения антибиотиков, ранней лабораторной диагностики и повышения медицинской грамотности населения. [3,5]

Ключевые слова: *антибиотикорезистентность, MRSA, бета-лактамаза, карбапенем-резистентность, мультирезистентные бактерии, антимикробная терапия, внутрибольничные инфекции. [3,5]*

1. Introduction

The discovery of antibiotics represents one of the greatest achievements in the history of modern medicine. Since the introduction of penicillin into clinical practice in the twentieth century, antibacterial agents have significantly reduced mortality associated with infectious diseases and improved the outcomes of surgical procedures, transplantation, oncology treatment, and intensive care medicine. However, the widespread and often irrational use of antibiotics has accelerated the emergence of antimicrobial resistance.

Antimicrobial resistance occurs when microorganisms such as bacteria, viruses, fungi, and parasites evolve mechanisms that reduce or eliminate the effectiveness of antimicrobial agents.

Among these, bacterial resistance to antibiotics has become the most concerning issue due to its rapid global spread and clinical impact. According to the World Health Organization (WHO), antimicrobial resistance is currently one of the top ten global public health threats facing humanity. [1]

The burden of antimicrobial resistance continues to increase worldwide. Recent epidemiological reports indicate that multidrug-resistant pathogens are responsible for millions of infections annually, leading to prolonged hospitalization, increased healthcare costs, therapeutic failure, and elevated mortality rates. Hospital-acquired infections caused by methicillin-resistant Staphylococcus aureus (MRSA), carbapenem-resistant Enterobacteriaceae, Pseudomonas aeruginosa, and Acinetobacter baumannii remain particularly problematic in intensive care units and immunocompromised patients. [3]

In addition, the development of new antibiotics has slowed considerably over the past two decades, while bacterial adaptation mechanisms continue to evolve rapidly. Consequently, understanding the molecular basis, epidemiology, and prevention strategies of antibiotic resistance has become a priority direction in modern biomedical research.

The aim of this review article is to analyze the major causes and mechanisms of antibiotic resistance, evaluate current epidemiological trends, and discuss modern strategies for prevention and control.

2. Materials and Methods

This study was conducted as a narrative literature review. Scientific publications related to antimicrobial resistance published between 2020 and 2025 were systematically searched and analyzed using international databases, including PubMed, Scopus, Google Scholar, WHO reports, and CDC surveillance publications.

The search strategy included the following keywords and combinations: “antimicrobial resistance,” “antibiotic resistance,” “MRSA,” “carbapenem-resistant bacteria,” “multidrug-resistant pathogens,” “nosocomial infections,” and “antimicrobial stewardship.” [3,5]

Inclusion criteria were:

- peer-reviewed scientific articles;
- WHO and CDC epidemiological reports;
- English-language publications;
- studies focusing on bacterial resistance mechanisms and clinical implications.

Exclusion criteria included:

- duplicate studies;
- publications lacking scientific methodology;
- non-peer-reviewed sources;
- studies unrelated to bacterial antimicrobial resistance.

The collected data were analyzed using comparative, descriptive, and analytical approaches. Particular attention was given to epidemiological trends, molecular resistance mechanisms, clinically significant resistant pathogens, and preventive healthcare strategies.

3. Results

Major Causes of Antibiotic Resistance

The analysis identified several major factors contributing to the development and spread of antimicrobial resistance:

1. Irrational and inappropriate prescription of antibiotics;
2. Antibiotic use in viral infections;
3. Self-medication among the population;
4. Excessive use of antibiotics in agriculture and animal husbandry;
5. Inadequate infection-control measures in healthcare facilities;
6. Poor public awareness regarding rational antimicrobial use.

Mechanisms of Resistance

Bacteria develop resistance to antibiotics through multiple biological and genetic mechanisms.

1. Beta-Lactamase Production

Certain bacteria produce beta-lactamase enzymes capable of hydrolyzing beta-lactam antibiotics. Extended-spectrum beta-lactamases (ESBLs) are commonly identified in Klebsiella pneumoniae and Escherichia coli.

2. Efflux Pump Systems

Some bacteria possess membrane transport proteins that actively expel antibiotics from the bacterial cell, thereby reducing intracellular drug concentration. This mechanism is frequently observed in Pseudomonas aeruginosa.

3. Biofilm Formation

Biofilms protect microorganisms from external environmental factors and significantly decrease antibiotic penetration. Biofilm-associated infections are particularly difficult to eradicate in chronic and device-associated infections.

4. Genetic Mutations

Mutations in bacterial DNA may alter antibiotic target sites, reducing drug-binding affinity and promoting resistance development.

Table 1. Common Antibiotic Classes and Resistant Pathogens

Antibiotic Class	Common Resistant Pathogens
Penicillins	MRSA
Cephalosporins	Escherichia coli, Klebsiella pneumoniae
Carbapenems	Acinetobacter baumannii
Macrolides	Streptococcus pneumoniae
Fluoroquinolones	Pseudomonas aeruginosa

Table 2. Global Trends in Antimicrobial Resistance

Microorganism	Estimated Resistance Rate
MRSA	40–60%
Carbapenem-resistant Klebsiella pneumoniae	20–50%
Fluoroquinolone-resistant E. coli	30–70%
Multidrug-resistant Pseudomonas aeruginosa	15–35%

4. Discussion

The findings of this review demonstrate that antimicrobial resistance has evolved into a major global healthcare crisis. Gram-negative bacteria, particularly carbapenem-resistant Enterobacteriaceae and multidrug-resistant Pseudomonas aeruginosa, pose serious therapeutic challenges due to their extensive resistance profiles. [7,13]

Hospital-acquired infections caused by resistant microorganisms are associated with prolonged hospitalization, increased healthcare expenditures, and elevated mortality rates.

Intensive care units remain especially vulnerable because of invasive procedures, broad-spectrum antibiotic exposure, and immunocompromised patient populations.

MRSA continues to be one of the leading causes of healthcare-associated infections worldwide. Similarly, carbapenem-resistant Gram-negative bacteria are increasingly associated with severe bloodstream infections and ventilator-associated pneumonia. [3,5]

One of the most effective approaches to combating antimicrobial resistance is the implementation of antimicrobial stewardship programs.

These programs aim to optimize antibiotic prescribing practices, reduce unnecessary antimicrobial exposure, and improve patient outcomes. [15]

Furthermore, strengthening laboratory diagnostic capacity is essential for early pathogen identification and susceptibility testing. Rapid microbiological diagnostics allow clinicians to prescribe targeted therapy instead of empirical broad-spectrum treatment.

Public health education also plays a crucial role. Increasing awareness regarding rational antibiotic use may significantly reduce self-medication and inappropriate antimicrobial consumption.

Despite considerable scientific advances, the development of new antibacterial agents remains insufficient compared with the rapidly evolving resistance mechanisms of microorganisms. Therefore, international cooperation, surveillance systems, and innovative therapeutic approaches are urgently needed.

5. Conclusion

Antimicrobial resistance represents one of the most critical challenges of modern medicine.

The rapid emergence of multidrug-resistant microorganisms significantly complicates the treatment of infectious diseases and threatens global healthcare security.

The present review demonstrates that irrational antibiotic use, insufficient infection-control practices, self-medication, and limited public awareness are major drivers of resistance development. Gram-negative multidrug-resistant pathogens, particularly carbapenem-resistant strains, have become a major concern in clinical practice. [7,13]

Effective prevention and control of antimicrobial resistance require rational antibiotic prescribing, implementation of antimicrobial stewardship programs, improvement of laboratory diagnostics, and continuous public health education. In addition, further scientific research focused on novel antimicrobial agents and alternative therapeutic strategies remains essential. [15]

Without urgent global intervention, antimicrobial resistance may seriously undermine the effectiveness of modern medical treatment in the future.

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