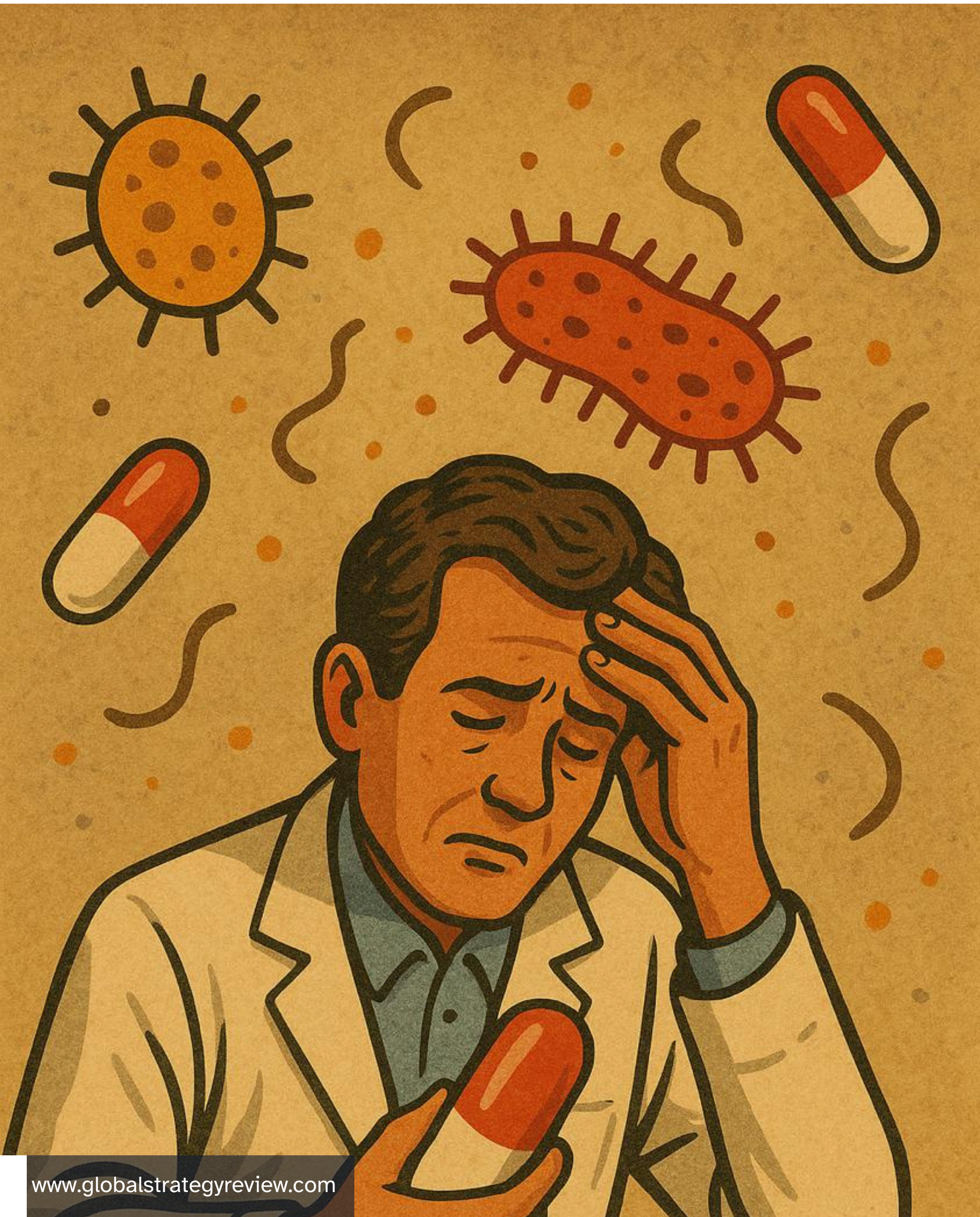
The Healthcare Review
Article V
GSR
Beirut, LB

The Antibiotic Resistance Crisis: Are We Losing the Battle?

Naji Mansour



The Antibiotic Resistance Crisis - Are We Losing the Battle?

Naji Mansour

Global Strategy Review: The Healthcare Review Series

17-08-2025

1. Introduction

Amongst a myriad of remarkable, modern medical advances, antibiotics stand out as a significant development. Thanks to antibiotics, thousands of lives have been preserved, transforming deadly infections into manageable medical situations. Through his 1928 breakthrough of penicillin, Alexander Fleming launched a medical revolution that allowed for life-saving operations, cancer treatments, and organ transplants to take place more regularly. The medical breakthroughs from antibiotics are encountering a critical threat because of antibiotic resistance.

Over time, bacteria evolve to create resistance against drugs that were intended to eliminate them. This rapidly accelerating problem jeopardizes all medical advancements made over the past decades, threatening to endanger worldwide health security, economic stability, and food security.

The absence of solutions to antibiotic resistance creates extensive problems that impact both young and old people throughout every region of the world. The escalating threat stems from excessive and improper antibiotic usage, which occurs in healthcare facilities and agricultural operations. The situation worsens because of poor infection control practices and the absence of new antibiotic development. It has become more critical than ever with the recent emergence of new "superbug" strains requiring immediate proactive action.

Recent studies alongside multiple policy reports have resulted in antibiotic resistance being raised to the status of ‘primary discussion subject’ within global health research. The World Health Organization (WHO) reported in 2019 that antibiotic resistance endangers both contemporary medical effects, worldwide economic stability, and food production systems. The number of untreatable infections is on the rise due to drug resistance, according to Jim O'Neill (2016), who reported the increased prevalence of pathogens such as MRSA and CRE. The improper use of antibiotics in both medical facilities and non-medical environments alike drives the resistance crisis, most commonly in low-income countries, where antibiotics can be obtained without prescription (Laxminarayan et al., 2016). A solution to these problems requires multiple approaches through international collaborations, which would provide equal access to new antibiotics while promoting responsible antibiotic use in every sector. Through its One Health initiative, the WHO underlines the need for a complete health perspective that recognizes human health links to both animal health and environmental health in antimicrobial resistance prevention (WHO, 2023). The crisis requires countries to unite their efforts and resources to protect antibiotic effectiveness for future populations.

2. The Scope of the Crisis

The worldwide antibiotic resistance problem expands day by day, producing noticeable impacts across health domains as well as economic and social realms. WHO reports that antibiotic resistance causes more than 700,000 annual deaths, with experts predicting that this number will surge sharply until it reaches 10 million deaths per year by 2050.

Significant health threats include superbugs such as Methicillin-resistant Staphylococcus aureus (MRSA), multidrug-resistant tuberculosis (MDR-TB), and carbapenem-resistant Enterobacteriaceae (CRE). These pathogens present treatment challenges because of their resistance to various antibiotics, therefore limiting available treatment options and making common infections more difficult to manage. The World Health Organization reports that

multidrug-resistant tuberculosis leads to the death of more than 200,000 people every year (WHO, 2023).

Antibiotic resistance creates a significant economic burden, costing millions of dollars every year. The Centers for Disease Control and Prevention (CDC) reports that the annual expenses for antibiotic-resistant infections within U.S. healthcare facilities amount to $20 billion; meanwhile, patient illness-related productivity losses total $35 billion.

The financial impact of antibiotic resistance within low-income nations stands as the most severe, ultimately depleting scarce healthcare resources and significantly raising infection treatment expenses. These effects are furthered by widespread improper antibiotic use and weak healthcare systems. In contrast, high-income countries have the benefit of advanced medical frameworks and infection control standards.

Due to insufficient attention towards antibiotic resistance, the world faces a dual threat of enormous economic costs coupled with disastrous global health risks that could threaten global catastrophe. The World Bank (2017) published a detailed report predicting that the worldwide economy would decrease by 3.8% by 2050 because of resistant infections' financial impact, while low- and middle-income countries will bear the greatest economic losses. The Centers for Disease Control and Prevention (CDC, 2019) indicates that antibiotic-resistant bacteria lead to extended hospitalization durations, elevated healthcare expenses, and reduced employee productivity caused by illness-related absence from work. Antibiotic-resistant pathogens exist not only within healthcare facilities but also in soil, water systems, and urban air environments (Ventola, 2015). The global expansion of trade and international travel has accelerated the worldwide spread of resistant bacteria, making the crisis a matter of international concern (Laxminarayan et al., 2016). According to Time (2024), the death toll from superbugs will exceed 39 million per year by 2050 unless major intervention measures are implemented. The current situation demands international collaboration to stop the health crisis from becoming an unmanageable worldwide disaster.

3. Causes of Antibiotic Resistance

Antibiotic resistance is driven by a variety of interconnected factors:

Overuse and Misuse in Human Healthcare

Excessive prescription and the improper use of antibiotics serve as the primary causes of antibiotic resistance development. Patients frequently request antibiotics for viral infections that ordinary antibiotics cannot treat. This becomes a matter of concern when patients stop their medication before completion, thus allowing leftover bacteria to survive. Research indicates that hospitals and outpatient facilities prescribe unnecessary antibiotics to approximately 50% of their total prescriptions (Centers for Disease Control and Prevention, 2022).

Use in Agriculture and Animal Husbandry

The widespread use of antibiotics on farm animals remains a key cause in the development of antibiotic resistance. The practice of giving antibiotics to healthy animals to enhance growth and disease prevention results in resistant microorganisms that transfer between humans through food systems and environmental pathways, as well as physical contact. In order to effectively suppress

resistance development, the World Health Organization (WHO, 2017) demands enhanced regulatory control to decrease antibiotic utilization in agricultural operations.

Poor Infection Control Practices

The uncontrolled transmission of infections within healthcare environments represents an essential component of antibiotic resistance. Healthcare facilities that do not establish proper hygiene and sanitation procedures allow for the spread of resistant pathogens, leading to hospital-acquired infections. For example, a 2019 outbreak of carbapenem-resistant *Klebsiella pneumoniae* in a New York hospital was traced back to inadequate hand hygiene and contaminated equipment, resulting in multiple patient deaths and prolonged hospital stays (Guh et al., 2020).

Lack of New Antibiotic Development

The pharmaceutical industry has shown reduced interest in developing new antibiotics over the past decades. Due to high costs, the industry has now shifted towards the development of other pharmaceutical products, such as (examples), where profits are far greater but often provide less extensive treatment. This, coupled with the fact that bacteria tend to evolve at incredibly fast rates, makes it increasingly difficult for the few existing antibiotics to combat such resistant bacteria.

Recent studies demonstrate that excessive medical prescriptions combined with self-administered medications serve as the principal causes of antibiotic resistance throughout both developed and developing countries. According to the National Institute of Allergy and Infectious Diseases (2010), physicians persist in writing unnecessary antibiotic prescriptions due to patient demands and the lack of time for diagnostic tests. Furthermore, according to economists Rayan Laxminarayan et al. (2016), the widespread availability of unprescribed antibiotics in numerous low-income countries opens the door for misuse. The agricultural industry plays a key role in antibiotic consumption because it uses approximately 80% of U.S. antibiotics to promote livestock growth and prevent diseases (Ventola, 2015). The practice occurs throughout various sectors, in turn producing antibiotic-resistant strains that are transmitted through food pathways with harmful health consequences for humans (WHO, 2023). The crisis worsens because pharmaceutical manufacturing plants discharge their waste products into local water systems, creating reservoirs for resistance genes (European Centre for Disease Prevention and Control, 2015). Bilal Aslam et al. (2018) pointed out that managing antibiotic usage in all sectors demands regulatory oversight, stricter medication regulations, and public education.

4. Consequences of Antibiotic Resistance

The consequences of antibiotic resistance are vast and multifaceted, impacting healthcare, the economy, and even food security.

Impact on Healthcare

The emergence of antibiotic resistance presents additional challenges for the medical treatment of infections, making previously curable conditions increasingly more difficult to treat. Treatments and procedures for both cancer and chronic illnesses rely heavily on antibiotics for infection prevention and treatment. The absence of necessary medical instruments elevates treatment risks, which often results in extended hospitalization time along with more costly interventions and, consequently, increased patient mortality.

Economic Impact

Antibiotic resistance creates consequential financial repercussions that affect nearly every segment of the healthcare system. The treatment of resistant infections creates both immediate treatment expenses as well as long-term medical effects. Along with significant decreases in productivity, family, healthcare systems, and government institutions are forced to bear excessive financial costs. Furthermore, developing nations often face an even heavier burden because they possess limited resources and restricted access to new antibiotics.

Food Security and Agricultural Productivity

Resistant pathogens can easily be spread from animals to humans, potentially contaminating the food supply and ultimately posing a significant threat to food security. Moreover, resistant bacteria in agriculture may result in the reduction of livestock productivity, posing dangerous risks to global food systems and agriculture-based economies.

Antibiotic resistance creates conditions that threaten the core functions of antibiotic treatments, ultimately posing a high risk in carrying out modern medical procedures. The prevalence of resistant infections makes treatments dependent on effective antibiotics, such as chemotherapy, organ transplants, and routine surgeries, increasingly risky (Cleveland Clinic, 2023). According to Gandra et al. (2021), the once-simple infections now need stronger or more costly second-line treatments, which provide diminished treatment success. Because antibiotic-resistant infections require patients to stay longer in hospitals and receive additional medical procedures, financial strain and mortality rates increase (Gandra et al., 2021). Furthermore, the spread of resistance threatens agricultural productivity because it leads to decreased livestock yields, which puts food security at risk (Aslam et al., 2018). The National Foundation for Infectious Diseases (2023) predicts that zoonotic diseases that spread from animals to humans will increase because resistant bacteria transfer between species. This complicated crisis demands immediate worldwide alliances because the absence of antibiotic resistance containment will bring back the deadly nature of common infections that medical science had previously overcome.

5. Strategies to Combat Antibiotic Resistance

Efforts to combat antibiotic resistance must be multifaceted, combining public awareness, policy measures, research, and global collaboration. The following strategies are essential to mitigate the crisis:

Public Awareness and Education

The fight against antibiotic resistance requires greater awareness and education, as the public often remains unaware of the dangers posed by improper antibiotic use. The public health sector should run awareness campaigns to teach people how to use antibiotics properly by finishing their prescriptions and not taking antibiotics when they are not needed.

Educational programs must focus specifically on healthcare providers. Doctors should follow antibiotic prescribing guidelines while also selecting alternative treatments when appropriate. Better public understanding of antibiotic resistance helps decrease antibiotic use in cases where antibiotics are not necessary for treating viral infections.

Policy Measures

Governments play a vital role in fighting antibiotic resistance through their establishment and enforcement of laws and regulations that control antibiotic usage. Many nations have established

new rules that restrict antibiotic administration to healthy farm animals. Governments should enhance healthcare infection control practices while maintaining hospital hygiene standards and promoting antibiotic usage responsibility.

The development of new antibiotics requires appropriate financial motivation for pharmaceutical companies. The high development costs and minimal financial returns have become major barriers to innovation within this field. Governments should establish financial support systems through subsidies or alternative programs to enhance the profitability of antibiotic and alternative therapy research for companies.

Research and Innovation

The most urgent requirement to combat antibiotic resistance involves developing fresh antibiotics alongside non-traditional therapeutic approaches. The development of new antibiotics has slowed down in recent years due to financial obstacles and regulatory hurdles. Researchers are currently investigating the potential benefits of phage therapy and antimicrobial peptides as alternative treatment methods.

In parallel, efforts are also being made to improve diagnostic accuracy, ensuring that both traditional and emerging therapies are used only when truly necessary. Rapid diagnostic tools under development will help medical professionals determine when antibiotics are truly needed for patient treatment. The diagnostic instruments help doctors perform fast bacterial infection detection while distinguishing between bacterial infections and viral diseases, which enhances their decision-making process regarding antibiotic prescriptions.

Global Collaboration

Created by international circumstances, antibiotic resistance demands coordinated global solutions for a resolution. The World Health Organization (WHO), together with the Centers for Disease Control and Prevention (CDC) and the Global Antibiotic Research and Development Partnership (GARDP), are collaborating internationally to develop responses against antibiotic resistance (Outterson et al., 2024). At the same time, these organizations set guidelines for how antibiotics should be used properly and enable various countries to share information while building resource networks amongst each other.

The global collaboration process includes efforts to enhance healthcare accessibility in low-income nations while developing their medical infrastructure systems. The support of these countries remains essential to stop antibiotic-resistant infections from spreading more widely.

A successful approach to addressing antibiotic resistance calls for combined strategies that unite scientific inventions with policy modifications and public commitment. Bacteriophage therapy represents a promising solution to fight antibiotic resistance because this virus-based therapeutic method specifically kills bacteria (Aslam et al., 2018). Traditional antibiotics differ from phages because this virus-based treatment focuses only on harming specific bacteria while preserving beneficial microbes in the environment. Moreover, research demonstrates that antimicrobial peptides (AMPs) represent a promising alternative therapy because they can destroy bacteria effectively without creating resistance (Ventola, 2015). The U.S. PASTEUR Act serves as a policy measure that provides pharmaceutical companies with government-backed purchases and financial benefits to encourage new antibiotic development (Vox, 2024). The WHO manages global surveillance efforts through the Global Antimicrobial Resistance and Use Surveillance System

(GLASS) to monitor resistance development alongside building international policy frameworks (WHO, 2023). Strengthening these systems would improve the streaming of outbreak detection as well as resource distribution. The prevention of antibiotic misuse requires public awareness campaigns to be implemented in areas where antibiotic misuse is most prevalent (Healthdata.org, 2023). A successful approach to addressing antibiotic resistance calls for combined strategies that unite scientific inventions with policy modifications and public commitment.

6. Challenges

Despite the growing awareness of antibiotic resistance and the implementation of strategies to combat it, several challenges persist:

Barriers to Implementation in Low-Resource Settings

Developing nations with limited resources encounter major obstacles when trying to deploy successful intervention programs. The combination of restricted healthcare services, substandard sanitation practices, and weak infection control protocols creates obstacles for controlling resistant infections. The scarcity of affordable diagnostic tools, as well as the improper use of antibiotics in these regions, exacerbate the situation. The resolution of these challenges requires international backing, although available resources prove inadequate. For example, in India, a 2017 study found that over 50% of antibiotics were dispensed without a prescription, contributing significantly to the rise of multidrug-resistant organisms, particularly in urban slums with poor sanitation and overcrowding (Chokshi et al., 2019).

The major obstacle to combating antibiotic resistance stems from the substantial gap in the quality of healthcare systems between wealthy and poor nations. For example, in Nigeria, limited access to diagnostics and the widespread sale of antibiotics without prescriptions have contributed to rising rates of drug-resistant infections, especially in rural and peri-urban areas. A 2021 review noted that nearly 70% of patients in some Nigerian hospitals receive antibiotics without proper diagnostic confirmation, highlighting systemic issues in stewardship and healthcare delivery (Olayinka et al., 2021).

The efficiency of diagnostic equipment, coupled with appropriate disease tracking systems and infection prevention protocols, supports high-income countries. In contrast, low- and middle-income nations face substantial healthcare accessibility issues, as explained in Laxminarayan et al. (2016). The inequity of healthcare systems between rich and poor nations results in excessive antibiotic use, as patients in underdeveloped areas tend to seek treatment through self-medication and over-the-counter drugs without medical supervision (WHO, 2023). Consequently, rapid bacterial resistance spreads more rapidly in these regions because these treatments often overlook proper sanitation services and inadequate infection control practices (World Bank, 2017). Healthcare system funding shortages create additional challenges since hospitals in these areas lack the essential staff members, proper training, and necessary infrastructure to fight antibiotic-resistant infections effectively. The European Centre for Disease Prevention and Control (2015) determined through research that specific international funding, together with capacity-building programs, must address these inequalities. Global health security remains at risk because insufficient worldwide backing of resistance control measures creates fragmented efforts that enable resistant strains to spread freely between borders.

Global Inequities

The gap in the availability of medical resources between different nations creates additional challenges for controlling antibiotic resistance. Countries with higher incomes possess better access to antibiotics, along with superior infection control practices and advanced healthcare systems, which reduce the problem. In contrast, lower-income countries lack sufficient medical resources, leading to restricted access to health care professionals and medicines, all while their antibiotic resistance rates exceed those of other countries. For instance, a 2018 WHO report showed that antibiotic resistance rates for common infections like *E. coli* and *Klebsiella pneumoniae* were significantly higher in parts of Africa and Southeast Asia compared to high-income countries. The global response would be to resolve these inequalities for effective and fair outcomes. Organizations like the WHO, GARDP, and the UN Interagency Coordination Group on Antimicrobial Resistance are leading these efforts, pushing for investment in healthcare infrastructure, surveillance systems, and equitable access to diagnostics and treatments.

The unequal healthcare system creates two major problems by restricting antibiotic availability and preventing proper infection control practices, enabling resistant bacteria to multiply (Laxminarayan et al., 2016). Many developing nations allow patients to obtain antibiotics without a prescription, which results in improper use and self-treatment of medications (National Foundation for Infectious Diseases, 2023). Multinational pharmaceutical companies focus their strategy on wealthier markets rather than poorer ones, leading to unequal access in developing countries to the latest effective antibiotic treatments (O'Neill, 2016). The continuing spread of resistant bacteria will damage worldwide health initiatives while worsening social disparities among population groups since these inequities remain largely unresolved. However, GARDP (2021) supports the implementation of fair distribution systems, which provide essential antibiotics and management resources to every country to combat antibiotic resistance effectively.

Long-Term Prospects

Although progress has been achieved, the situation regarding antibiotic resistance remains difficult. The battle requires a long-term combined effort of governments, healthcare providers, and researchers, along with public participation. The future success of combating this issue depends on ongoing research investment, together with global partnership development and thorough antibiotic practice implementation.

The successful management of antibiotic resistance requires extended international working relationships, scientific innovation, and constant political support. Davies (2024) states that although public understanding of the crisis has improved, the present research and policy transformation rate remains inadequate to match the quick evolution of resistant bacteria. Researchers have begun investing in artificial intelligence diagnostics because these emerging technologies allow better early detection and precise treatment of resistant infections (Vox, 2024). The advancement of new antibiotic development programs alongside bacteriophage therapy and CRISPR-based antimicrobial research depends heavily on significant financial commitment (Aslam et al., 2018). The creation of treaties dedicated to antibiotic access equity and standardized international care practices would establish a systematic approach for worldwide cooperation (Laxminarayan et al., 2016). Long-term funding and political support are necessary to guarantee that these initiatives achieve their objective. The consequence of the lack of continuous global collaboration will allow for antibiotic resistance to become a deadlier killer than cancer by 2050, thus undoing medical advancements from the past decades and threatening the operational effectiveness of contemporary healthcare systems (Time, 2024).

7. Conclusion

The worldwide health emergency of antibiotic resistance endangers all medical advancements made during the past decades. Bacteria learn to fight antibacterial medicines, increasingly threatening human health, food production, and economic stability. This article demonstrated the critical nature of the problem while explaining its fundamental origins and demanding immediate solutions through multiple intervention methods.

We need to take immediate action against antibiotic resistance as the situation will eventually become impossible to reverse. All stakeholders, including governmental leaders, health professionals, and scientific researchers, must come together with the general society to combat antibiotic resistance. Combined efforts in raising public understanding through organized policies, scientific advancements, and multinational partnerships will help reduce antibiotic resistance while sustaining antibiotics as effective infection-fighting tools.

Society must accomplish rapid joint action throughout every sector to protect current medical practices. We still have not answered whether humanity will win or lose against antibiotic resistance, as the solutions will emerge based on how well we unite to face the challenge.

The situation regarding antibiotic resistance stands as an immediate global threat that endangers modern healthcare and the entire global structure of public health. WHO (2023) warns that inaction at present will lead to millions of deaths annually and a significant loss of medical progress from the last hundred years. The proposed international antimicrobial resistance treaties align with climate agreements by establishing nationwide collaboration for life-saving antibiotic distribution (Laxminarayan et al., 2016). These global organizations, including GARDP (2021) and the CDC, form partnerships to conduct essential research and execute surveillance activities, delivering equitable healthcare services for a comprehensive anti-CR fight. Confirmed by the World Bank (2017), global GDP losses from antibiotic resistance will amount to trillions of dollars between now and 2050. Science laboratories and governments must combine their efforts to create solutions to the emerging problem at hand. Our future depends on united efforts to protect antibiotics from future generations while stopping the regression of medical achievements (Davies, 2024).

References

1. World Health Organization (2023). "Antibiotic Resistance." World Health Organization. https://www.who.int/news-room/fact-sheets/detail/antibiotic-resistance
2. Centers for Disease Control and Prevention (2022). "Antibiotic Resistance Threats in the United States, 2022." CDC. https://www.cdc.gov/drugresistance/threat-report-2022.html
3. Gandra, S. et al. (2021). "The economic burden of antibiotic resistance in the United States." *Clinical Infectious Diseases*, 72(11): 2273-2280.
4. World Health Organization (2021). "Global Action Plan on Antimicrobial Resistance." https://www.who.int/antimicrobial-resistance/global-action-plan
5. GARDP (2021). "The Global Antibiotic Research and Development Partnership." https://www.gardp.org
6. Centers for Disease Control and Prevention. (2023, October 3). *Antimicrobial resistance facts and stats*. https://www.cdc.gov/antimicrobial-resistance/data-research/facts-stats/index.html
7. World Health Organization. (2023, July 28). *Vaccines could avert half a million deaths associated with antimicrobial resistance a year*. https://www.who.int/news/item/28-07-2023-vaccines-could-avert-half-a-million-deaths-associated-with-anti-microbial-resistance-a-year
8. Centers for Disease Control and Prevention. (2023, April 17). *About antimicrobial resistance*. https://www.cdc.gov/antimicrobial-resistance/about/index.html
9. Centers for Disease Control and Prevention. (2023, April 17). *Antimicrobial resistance: Causes and how it spreads*. https://www.cdc.gov/antimicrobial-resistance/causes/index.html
10. Centers for Disease Control and Prevention. (2023, April 17). *Antibiotic resistance threats in the United States*. https://www.cdc.gov/drugresistance/biggest-threats.html
11. World Health Organization. (2023, July 28). *Antimicrobial resistance*. https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance
12. Australian Government Department of Health. (2021, November 1). *What causes antimicrobial resistance?*. https://www.amr.gov.au/about-amr/what-causes-amr
13. National Institute of Allergy and Infectious Diseases. (2010, December 30). *Causes of antimicrobial (drug) resistance*. https://www.niaid.nih.gov/research/antimicrobial-resistance-causes
14. European Centre for Disease Prevention and Control. (2015, November 18). *Factsheet for the general public - Antimicrobial resistance*. https://www.ecdc.europa.eu/en/antimicrobial-resistance/facts/factsheets/general-public
15. Healthdata.org. (2023, October 3). *Antimicrobial resistance (AMR)*. https://www.healthdata.org/research-analysis/health-risks-issues/antimicrobial-resistance-amr

16. Cleveland Clinic. (2023, April 17). *Antibiotic resistance: What is it, complications & treatment*. https://my.clevelandclinic.org/health/articles/21655-antibiotic-resistance

17. Cedars-Sinai. (2023, April 17). *Antibiotic resistance*. https://www.cedars-sinai.org/health-library/diseases-and-conditions/a/antibiotic-resistance.html

18. National Foundation for Infectious Diseases. (2023, October 3). *Antibiotic resistance*. https://www.nfid.org/antibiotic-resistance/

19. Ventola, C. L. (2015). The antibiotic resistance crisis: Part 1: Causes and threats. *Pharmacy and Therapeutics*, 40(4), 277–283. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4378521/

20. Aslam, B., Wang, W., Arshad, M. I., Khurshid, M., Muzammil, S., Rasool, M. H., ... & Baloch, Z. (2018). Antibiotic resistance: a rundown of a global crisis. *Infection and Drug Resistance*, 11, 1645–1658. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6188119/

21. Laxminarayan, R., Matsoso, P., Pant, S., Brower, C., Rottingen, J. A., Klugman, K., & Davies, S. (2016). Access to effective antimicrobials: a worldwide challenge. *The Lancet*, 387(10014), 168–175. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)00474-2/fulltext

22. O'Neill, J. (2016). Tackling drug-resistant infections globally: Final report and recommendations. *Review on Antimicrobial Resistance*. https://amr-review.org/sites/default/files/160518_Final%20paper_with%20cover.pdf

23. World Health Organization. (2019). *No time to wait: Securing the future from drug-resistant infections*. https://www.who.int/publications/i/item/no-time-to-wait-securing-the-future-from-drug-resistant-infections

24. Centers for Disease Control and Prevention. (2019). *Antibiotic resistance threats in the United States, 2019*. https://www.cdc.gov/drugresistance/pdf/threats-report/2019-ar-threats-report-508.pdf

25. World Health Organization. (2017). *Global priority list of antibiotic-resistant bacteria to guide research, discovery, and development of new antibiotics*. https://www.who.int/publications/i/item/global-priority-list-of-antibiotic-resistant-bacteria

26. World Health Organization. (2015). *Global action plan on antimicrobial resistance*. https://www.who.int/publications/i/item/9789241509763

27. Centers for Disease Control and Prevention. (2023, April 17). *Antibiotic use in the United States, 2022 update: Progress and opportunities*. https://www.cdc.gov/antibiotic-use/stewardship-report/pdf/stewardship-report-2022-H.pdf

28. World Health Organization. (2023, July 28). *Global antimicrobial resistance and use surveillance system (GLASS) report: 2022*. https://www.who.int/publications/i/item/9789240062702

29. Centers for Disease Control and Prevention. (2023, April 17). *Be antibiotic aware: Smart use, best care*. https://www.cdc.gov/antibiotic-use/index.html

30. Davies, S. (2024, November 15). *'It is a pandemic': UK's envoy on superbugs says scale of threat underestimated*. The Guardian. This article discusses the underestimated global threat of antimicrobial resistance, highlighting the urgency of addressing the crisis. https://www.theguardian.com/society/2024/nov/15/superbugs-antimicrobial-resistance-antibiotics-threat-pandemic-sally-davies?

31. Time. (2024, September 18). *Superbugs Could Kill 39 Million People by 2050, Study Warns*. This study warns about the potential for superbugs to cause significant mortality by 2050 if current trends continue. https://time.com/7021922/superbugs-amr-lancet-study/

32. Vox. (2024, August 10). *Antibiotics are failing. The US has a plan to launch a research renaissance*. This article explores legislative efforts in the U.S. to combat antibiotic resistance by promoting the development of new antibiotics. https://www.vox.com/future-perfect/367247/antibiotic-resistance-bacteria-pasteur-act-big-pharma

33. Outterson, K., et al. *Advancing global antibiotic research, development and access*. *Nature Medicine* **30**, 2432–2443 (2024). https://doi.org/10.1038/s41591-024-03218-w

34. Chokshi, A., Sifri, Z., Cennimo, D., & Horng, H. (2019). Global contributors to antibiotic resistance. *Journal of Global Infectious Diseases*, *11*(1), 36–42. https://doi.org/10.4103/jgid.jgid_110_18

35. Olayinka, B. O., Onyedibe, K. I., & Olayinka, A. T. (2021). Antimicrobial resistance in Nigeria: Progress and challenges. *Infectious Diseases: Research and Treatment*, *14*, 1–9. https://doi.org/10.1177/11786337211008376

36. Guh, A. Y., et al. (2020). Epidemiology and prevention of carbapenem-resistant *Klebsiella pneumoniae* outbreaks in healthcare settings. *Clinical Infectious Diseases*, *71*(6), 1284–1290. https://doi.org/10.1093/cid/ciz945

37. World Health Organization. (2017). *Stop using antibiotics in healthy animals to prevent the spread of antibiotic resistance*. WHO. https://www.who.int/news/item/07-11-2017-stop-using-antibiotics-in-healthy-animals-to-prevent-the-spread-of-antibiotic-resistance