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Review article

Impact of antibiotics on public health

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ABSTRACT

One of the most important factors affecting public health is the use of antibiotics to treat infectious diseases. It is the most important medical discovery of the twentieth century, as antibiotics contributed to controlling many bacterial epidemics in addition to treating infectious diseases. The overuse of antibiotics, especially in developing countries, has a negative impact on public health. Therefore, many organizations have worked to establish strict policies for the use of antibiotics. The current study highlights the main types of antibiotics their mechanism of action against bacteria and their role in public health. Those who understood the One Health approach contributed to developing a policy and action plan to reduce the misuse of antibiotics as well as control bacterial resistance to these antibiotics. International organizations and research centers developed important policies and initiatives to limit the increase in bacterial resistance to antibiotics. The most important strategies used to confront antibiotic-resistant bacteria are to find alternative treatments, as well as developing health education fields, and provide warning curricula that highlight the danger of the decreased efficiency of antibiotics in treating diseases and epidemics. The ambitions for the future are great in this field, especially by supporting scientific research that relies on the use of alternatives to antibiotics in treating infectious diseases, in addition to setting clear policies that restrict unnecessary uses of antibiotics. It can be concluded from this study that the optimal and scientific use of antibiotics reflects positively on public health by reducing the outbreak of infectious diseases and that focusing on alternative antibacterial medicine will create hope for a better future against infectious diseases.

Keywords: Alternative medicine, Antibiotics, Public health, Resistance to antibiotics.

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1. INTRODUCTION

The most significant occurrences in the historical narrative of antibiotics encompass the unearthing of salvarsan in 1910, the revelation of penicillin in 1928, and the ensuing golden era of antibiotic discovery through natural sources during the mid-1950s. Alexander Fleming's momentous discovery of penicillin in 1928 brought about a revolution in the treatment of infections and catalyzed the progress of antibiotics [1]. The advent of artificial drugs, namely salvarsan and sulfonamides, also played an influential role in combating infectious diseases. The quest for novel antibiotics commenced in the 1940s and yielded the discovery of numerous pioneering antibiotics, thus marking the golden age of antibiotics [2]. Nevertheless, the progress in the development of new antibiotics has stagnated over the past three decades, while the prevalence of antibiotic resistance has increased [3].

Antibiotics have significantly increased life expectancy by effectively treating infections that were previously fatal. Since penicillin, scientists have developed various classes of antibiotics, such as cephalosporins, tetracyclines, and fluoroquinolones, broadening the spectrum of treatable infections. Antibiotics are fundamental in treating bacterial infections, from common ailments like wound infection, skin infection, bacterial diarrhea, and strep throat to more severe conditions like pneumonia and sepsis. Surgical advancements in antibiotics have played a crucial role in reducing postoperative infections and improving patient outcomes [4]. The use of prophylactic ant-

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antibiotics, such as cephalosporins, have become routine in surgical theaters to prevent surgical site infections. However, the emergence of multidrug-resistant bacteria has led to the need for alternative approaches, such as the use of probiotics, prebiotics, or synbiotics, to improve outcomes in abdominal and gastrointestinal surgery. The development of different generations of cephalosporins has significantly contributed to reducing hospital infections [5]. In colorectal surgery, identifying appropriate antibiotic regimens against likely pathogens and understanding the pharmacokinetics of these drugs has been crucial in improving outcomes. Technological advances, including nano-technology, have also improved the ability to detect, prevent, and treat surgical infections. These advancements are essential in combating the challenges posed by resistant and virulent strains of organisms [6]. Widespread use came to the challenge of antibiotic resistance as bacteria adapted and developed mechanisms to survive antibiotic exposure [7]. Antibiotics have significantly reduced mortality rates associated with bacterial infections, contributing to better public health outcomes. They've played a crucial role in preventing and controlling epidemics and outbreaks caused by bacterial pathogens [8]. By mitigating the impact of infectious diseases, antibiotics have facilitated improved access to healthcare, especially in underserved communities.

2. MECHANISM OF ANTIBIOTICS ACTION

Antibiotics work by exploiting differences between human and bacterial cells. They target specific sites in the bacteria, such as cell wall synthesis, protein synthesis, and nucleic acid replication, to inhibit their growth or kill them off [9]. Antibiotics can be used in combination to increase their effectiveness in treating infectious diseases. Combination therapy can broaden the antibiotic spectrum, reduce dosage and side effects, and control the emergence of resistance. The molecular mechanisms underlying antibiotic combinations and their effects on resistance development are still not fully understood, highlighting the need for further research and genetic validation [10]. Antibiotics are primarily used to cure and prevent infections by inhibiting the growth or killing off certain types of bacteria. However, the overuse of antibiotics has led to the development of bacterial resistance, making it more difficult to treat infections [11]. The immune system also plays a role in fighting infections, and healthcare professionals can take measures to help reduce cross-infection.

Antibiotics are categorized into several classes based on their chemical structure, mechanism of action, and the type of bacteria they target. Here are some of the main classes of antibiotics: Penicillins, the first discovered antibiotics, inhibit bacterial cell wall synthesis. They include penicillin V, penicillin G, amoxicillin, and ampicillin. They are effective against a wide range of bacteria. Cephalosporins, similar to penicillins, cephalosporins also target bacterial cell walls. They have different generations (1st to 5th), each with an expanded spectrum of activity against various bacteria. Macrolides, antibiotics like erythromycin, azithromycin, and clarithromycin inhibit bacterial protein synthesis. They are commonly used for respiratory tract infections and some sexually transmitted diseases. Tetracyclines, including doxycycline and minocycline, interfere with bacterial protein synthesis. They're effective against a broad spectrum of bacteria but are often avoided in children due to potential teeth discoloration. Aminoglycosides, these antibiotics, like gentamicin and streptomycin, disrupt bacterial protein synthesis. They are used to treat severe infections but can have side effects on the kidneys and hearing. Fluoroquinolones, such as ciprofloxacin and levofloxacin inhibit bacterial DNA synthesis. They are effective against a wide range of bacteria and are often used for urinary tract infections and respiratory infections. Sulfonamides and Trimethoprim, antibiotics inhibit different steps in bacterial folate synthesis. When combined (as in co-trimoxazole), they are synergistic and used for various bacterial infections. Glycopeptides, such as vancomycin and teicoplanin are examples. They target bacterial cell walls and are often reserved for treating serious infections caused by methicillin-resistant Staphylococcus aureus (MRSA) and other resistant bacteria. Carbapenems such as meropenem, imipenem, and doripenem belong to this class and are effective against a wide range of bacteria. They're often used in serious hospital-acquired infections. Lipopeptides, the daptomycin is an example that disrupts bacterial cell membranes, used mainly for skin and bloodstream infections [12,13].

Antibiotics exhibit various modes of action to combat bacterial infections. Understanding these mechanisms is crucial for developing effective treatment strategies and combating antibiotic resistance. Here are the primary modes of action of antibiotics against bacteria: Inhibition of cell wall synthesis, some antibiotics, like penicillins and cephalosporins, interfere with the synthesis of the bacterial cell wall. They target enzymes responsible for building the cell wall, leading to structural instability and bacterial cell lysis [14].

Inhibition of protein synthesis, i.e. macrolides, tetracyclines, aminoglycosides, and chloramphenicol disrupt bacterial protein synthesis by targeting different components of the bacterial ribosome. By interfering with protein production, these antibiotics hinder bacterial growth and reproduction [15]. Inhibition of nucleic acid synthesis, some antibiotics, such as fluoroquinolones and rifampin, disrupt the synthesis of bacterial DNA or RNA. They inhibit enzymes involved in DNA replication, transcription, or other nucleic acid processes, preventing bacteria from replicating their genetic material. Disruption of cell membrane function, like polymyxins and daptomycin act by disrupting the integrity of bacterial cell membranes. They interact with the cell membrane components, causing leakage of essential cellular contents and leading to bacterial death [16]. Inhibition of metabolic pathways, some antibiotics, such as sulfonamides and trimethoprim, interfere with specific metabolic pathways crucial for bacterial survival. They inhibit enzymes involved in essential metabolic processes like folic acid synthesis, ultimately disrupting bacterial growth. Blocking essential bacterial functions, some antibiotics such as fosfomycin and mupirocin interfere with critical bacterial functions. For instance, fosfomycin disrupts cell wall synthesis by inhibiting an enzyme involved in peptidoglycan production, while mupirocin inhibits bacterial protein synthesis [17]. Induction of reactive oxygen species (ROS), some antibiotics trigger the production of ROS within bacterial cells. This oxidative stress damages bacterial components, leading to cell death. Examples include certain classes of antibiotics like quinolones [18]. These many modes of action demonstrate how antibiotics are selective in their targeting of vital bacterial processes while avoiding harm to human cells. Bacteria may, however, evolve defense mechanisms against these medicines, including altering the locations of the antibiotic's target, secreting the antibiotic, or creating enzymes that render the antibiotic inactive. Comprehending these pathways is crucial in the development of novel medicines and tactics to counter the escalating problem of antibiotic resistance.

3. PUBLIC HEALTH CHALLENGES

The resistance to antibiotics poses multifaceted challenges in different healthcare settings, impacting treatment outcomes and elevating healthcare costs. The challenges of antibiotic resistance that relate to public health impact on the environment of hospitals. Hospitals often harbor antibiotic-resistant bacteria due to intensive antibiotic use. Nosocomial infections, such as Methicillin-resistant Staphylococcus aureus (MRSA) and multidrug-resistant Gram-negative bacteria, are prevalent [19]. Resistant infections in hospitals lead to longer hospital stays, increased morbidity, and mortality rates due to limited treatment options [20]. Treatment becomes challenging, requiring more potent, often more expensive, and sometimes toxic antibiotics. This complexity increases the risk of treatment failure [21]. Antibiotic resistance is not confined to hospitals. Community-acquired infections by resistant bacteria, like drug-resistant *Streptococcus pneumoniae* and *Enterococcus*, are rising [22]. Treating common infections becomes challenging in primary care settings due to increasing antibiotic resistance. This limitation affects the efficacy of standard treatments [23].

The Global Impact of resistance to antibiotics is that antibiotic-resistant bacteria transcend borders. Global travel facilitates the spread of resistant strains, making containment and treatment challenging [24]. Developing countries face increased mortality due to limited access to effective antibiotics, exacerbating the burden of infectious diseases [25]. Moreover, antibiotic resistance leads to prolonged illnesses, complex treatments, and the need for more expensive antibiotics, significantly elevating healthcare costs [26]. Longer hospital stays, additional diagnostic tests, and the need for more extensive care contribute to increased healthcare utilization and costs [26]. These challenges demonstrate the far-reaching impact of antibiotic resistance across diverse healthcare settings, emphasizing the urgent need for concerted efforts in surveillance, stewardship, and development of new antimicrobial strategies.

4. ONE HEALTH APPROACH

The interconnectedness of human health, animal health, and the environment about antibiotic use and resistance is integral to understanding the One Health concept. Antibiotics are extensively used in human medicine for treating infections. Similarly, in animal agriculture, they're used for disease prevention and growth promotion. The shared use contributes to the emergence and spread of resistant bacteria between animals and humans [27]. Resistant bacteria and resistance genes can move between humans, animals, and the environment through various pathways like direct contact, contaminated food, water, and environmental pollutants. This transmission underscores the interconnectedness of these ecosystems [28]. Antibiotics and resistant bacteria can persist in environmental reservoirs, such as soil, water bodies, and wastewater, due to agricultural runoff, pharmaceutical waste, and human/animal excretion. These reservoirs act as hotspots for the spread of resistance [29]. The One Health approach acknowledges the interdependency of human, animal, and environmental health and advocates collaborative efforts among healthcare, veterinary, and environmental sectors to address antibiotic resistance. This holistic approach integrates surveillance, stewardship, education, and research to mitigate the spread of resistance [30]. Implementing policies that regulate antibiotic use in humans, animals, and agriculture while promoting responsible practices is vital. Collaborative efforts involving health professionals, veterinarians, policymakers, and environmental scientists are essential to address this global challenge [31]. By recognizing the interconnectedness of these domains and adopting a One Health approach, interventions and policies can be designed to mitigate antibiotic resistance, emphasizing the need for joint actions across human, animal, and environmental health sectors

5. GLOBAL INITIATIVES AND POLICIES

Antibiotic resistance remains a critical global health threat, prompting concerted efforts by international organizations, governments, and healthcare stakeholders to address this challenge. Several initiatives and strategies have been established to combat antibiotic resistance and promote responsible antibiotic use worldwide.

a. World Health Organization (WHO) Initiatives: The WHO spearheads global efforts to address antibiotic resistance through various initiatives. The Global Action Plan on Antimicrobial Resistance, launched in 2015, outlines strategic objectives focusing on improving awareness, strengthening knowledge through surveillance, reducing infections, optimizing antibiotic use, and fostering innovation. The WHO also promotes the AMR Surveillance and Response System, enabling countries to monitor antibiotic resistance patterns and establish effective response mechanisms [32].

b. Global Antimicrobial Resistance Surveillance System (GLASS): GLASS, initiated by the WHO, aims to standardize antimicrobial resistance surveillance worldwide. It facilitates data sharing, harmonizes methodologies, and enhances global understanding of resistance patterns, crucial for informed decision-making and policy formulation [32].

c. National Action Plans (NAPs) and Policies: Numerous countries have developed NAPs aligned with the WHO Global Action Plan. These plans outline country-specific strategies, emphasizing surveillance, stewardship programs, infection control measures, research funding, and education to ensure prudent antibiotic use across healthcare, veterinary, and agricultural sectors [32,33].

d. Stewardship Programs in Healthcare Settings: Healthcare facilities globally have implemented antibiotic stewardship programs, promoting rational antibiotic use. These programs involve guidelines, education, and monitoring to optimize antibiotic prescriptions, reduce unnecessary usage, and prevent the spread of resistance [33].

e. Regulation and Legislation: Regulatory bodies in several countries have enforced regulations to control antibiotic use. Some nations restrict over-the-counter antibiotic sales, promote prescription-only access, and impose guidelines on antibiotic usage in agriculture to reduce overuse and misuse [33].

f. Public Awareness Campaigns: Public education campaigns aim to increase awareness about antibiotic resistance and the importance of prudent antibiotic use. These campaigns emphasize the consequences of misuse, promoting responsible antibiotic consumption and adherence to prescribed courses [34].

g. Research and Innovation: Investment in research and development of new antibiotics, alternative therapies, and diagnostic tools is crucial. Collaborative efforts between the public and private sectors focus on developing novel antimicrobial agents and technologies to combat resistant infections effectively [35].

h. Global Partnerships and Collaborations: International collaborations among governments, health agencies, pharmaceutical companies, academia, and non-governmental organizations foster a unified approach to combat antibiotic resistance. Partnerships facilitate knowledge sharing, resource allocation, and coordinated actions against this global threat [36]. The multifaceted approach encompassing surveillance, education, regulation, research, and global collaboration is essential to effectively address antibiotic resistance. However, sustained commitment, resource allocation, and coordinated efforts across sectors and nations are paramount to mitigate this pressing global health concern.

6. ALTERNATIVE MEDICATION

Emerging alternatives to traditional antibiotics include non-steroidal anti-inflammatory drugs (NSAIDs), herbal medicines, antimicrobial peptides (AMPs), bacteriophages and their lytic enzymes, vaccination, and nanotechnology [37]. In addition, targeting bacterial quorum sensing (QS) has shown promise as a potential approach to combat bacterial infections. QS Inhibitors have demonstrated positive outcomes in animal models, although the role of QS during human infections is still underexplored [38]. Furthermore, preserving the power of existing antibiotics through prudent use and implementing infection prevention and control measures are crucial strategies to defer the antimicrobial resistance (AMR) crisis [39]. Other alternatives being explored include vaccines, antibodies, pattern recognition receptors, probiotics, phytochemicals, metals, and antimicrobial enzymes [40].

Here we will focus on the two main antibiotic alternatives medicine such as bacteriophages and herbal medicine. Bacteriophages, often called phages, are viruses that infect and replicate within bacterial cells. They are ubiquitous in the environment, found in water, soil, and even within the human body. Bacteriophages have garnered significant interest for their potential in combating bacterial infections, particularly in the context of antibiotic resistance. They are a viable alternative to antibiotics in the treatment of bacterial infections. They can target specific types of bacteria without disrupting commensal bacterial populations [41]. Bacteriophage therapy has shown effectiveness and safety in clinical trials for various conditions, including diarrheal diseases in children [42]. The increasing resistance of bacterial strains to antibiotics has led to the exploration of bacteriophages as a potential treatment option. Bacteriophages have a proven history of use in the Eastern world and have been effective in treating multidrug-resistant infections. Phage therapy has also shown promise in dermatological conditions caused by specific bacteria. However, further research is needed to ensure the safety and efficacy of phage therapy in humans [43].

Herbal medicine offers a rich source of compounds with potential antibacterial properties, and ongoing research continues to explore their efficacy, safety, and mechanisms of action. However, further scientific investigation and standardization are necessary for their integration into mainstream medical practices. Herbal compounds often work through various mechanisms, such as disrupting bacterial cell walls, inhibiting protein synthesis, interfering with bacterial enzymes, or modulating the immune response, contributing to their antibacterial effects. Some herbal extracts or compounds have shown synergistic effects when used in combination with antibiotics, enhancing their efficacy against resistant bacteria and reducing the required antibiotic dosage [44]. Herbal medicines can vary in potency and quality due to differences in plant sources, extraction methods, and formulations, posing challenges in ensuring consistent efficacy. Ongoing research of several investigators aims to identify and isolate active compounds from plants, conduct clinical trials to validate their efficacy and safety, and explore their mechanisms of action against antibiotic-resistant bacteria [44].

7. PUBLIC AWARENESS AND EDUCATION

Public awareness campaigns and education are crucial in promoting responsible antibiotic use among healthcare providers. The public awareness campaigns help individuals grasp the concept of antibiotic resistance, emphasizing that misuse and overuse of antibiotics contribute to this growing problem [45]. Educating the public empowers individuals to understand when antibiotics are necessary, leading to informed discussions with healthcare providers [46]. Ongoing education programs for healthcare providers ensure they understand the appropriate use of antibiotics, fostering responsible prescribing practices [46]. Public education campaigns dispel myths about antibiotics, emphasizing that they are ineffective against viral infections, thereby reducing unnecessary demand and use [47]. Effective public awareness campaigns influence attitudes toward antibiotic use, encouraging responsible behaviors, such as completing prescribed courses and avoiding sharing antibiotics. The others found that the collaborative efforts between healthcare organizations, governmental bodies, and community groups amplify the impact of educational initiatives on responsible antibiotic use [48]. The campaigns use clear, accessible language to convey the risks of antibiotic misuse and empower individuals to make informed choices [49]. Preserving antibiotic efficacy of antibiotics, responsible antibiotic use ensures the continued effectiveness of antibiotics for future generations, preventing the spread of resistant infections [25]. Another reason is avoiding unnecessary antibiotic prescriptions decreases healthcare costs associated with prolonged illnesses and complex treatments due to resistant infections [50].

Public awareness campaigns and education serve as indispensable tools in fostering responsible antibiotic use among both healthcare providers and the general population. By disseminating accurate information and fostering behavioral change, these initiatives contribute significantly to combating antibiotic resistance and ensuring effective antibiotic therapy.

8. FUTURE PERSPECTIVES

The future perspectives of antibiotics in medicine involve addressing the challenges of antimicrobial resistance and the declining number of new antibiotics being developed. To combat resistance, there is a need for innovation in the discovery and development of antibiotics, including the exploration of alternative approaches such as narrow-spectrum drugs, bacteriophage, monoclonal antibodies, and vaccines [51]. Additionally, there is a focus on finding new sources and targets for antibiotics that may circumvent known resistance mechanisms. Emerging technologies and legislative initiatives offer hope in reversing the trend of antibiotic resistance and ensuring a viable marketplace for antibiotic innovation [52]. However, the low output of new antibiotics in recent years highlights the need to address the scientific challenges and barriers to discovery. Overall, the future of antibiotics in medicine requires investment in research and development, policy changes, and a judicious use of antibiotics based on microbiology, pharmacology, and genetics [53].

9. Conclusion

The current study addressed one of the most important issues directly related to public health, as the correct use of antibiotics plays an important role in creating a healthy environment with little exposure to infectious diseases. The most important problem associated with the imposed use of antibiotics is the increase in resistance to them, and this will lead to the emergence of a major health problem related to the outbreak of bacterial infectious diseases and the limited response to them. Therefore, it has to focus on scientific research that provides alternatives for treating infectious diseases in addition to establishing a strict policy that limits the uncontrolled use of antibiotics.

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Conflict of interest

The authors declare that they have no conflict of interests.

Ethical Approval

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Author contributions

Tesfaye Kassa: Conceptualization; Roles/Writing - original draft; Supervision; Validation.

Razaq HE Al-Sayidi: Formal analysis; Resources; Roles/Writing - original draft; Visualization; Writing - review & editing.

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