Prevention and Control Strategies for Antimicrobial Resistance: A One Health Approach

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Abstract

Antimicrobial resistance (AMR) is a global concern threatening national and international security, the global economy, and the health of people and animals. The overuse of antibiotics, particularly penicillin, has led to the development of resistance mechanisms, primarily due to drug abuse and overuse. AMR has emerged due to the rapid increase in infections and the lack of new antibiotics. The One Health approach, which combines environmental, animal, and human professionals, is essential for addressing AMR. Bacteria subjected to antimicrobial selection develop mobile genetic elements and resistance genes that can infect other bacteria. Lack of awareness about AMR is a primary cause of improper use of antibiotics. To prevent AMR, everyone should be aware of good sanitation, adhering to treatment recommendations, and understanding the dangers of antibiotic use. Antimicrobial classification can be used in risk management plans to prevent the use of therapeutically relevant drugs. Interventions like increased vaccines and nonantimicrobial disease management measures are also needed to reduce antibiotic consumption in animals. Important One Health initiatives to address AMR through enhanced awareness and comprehension, improved monitoring, infection prevention, and optimal utilization of antimicrobials across every field are also described. It also highlights how crucial it is to make regular expenditures in vaccine and antibiotic advancement and research to combat AMR. The One Health idea was incorporated into the implementation plans of numerous nations and worldwide organizations to combat the resistance to antibiotics. According to the chapter's conclusion, a cooperative One Health approach is essential to stopping the propagation of AMR, offering efficient treatments, and maintaining an inviting atmosphere.

Keywords: Antimicrobial resistance, AMR, One health approach

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Introduction

The worldwide financial system, human and animal health, and national and international security are all at risk from the complex and multifaceted issue of antimicrobial resistance (AMR) (Aslam et al., 2024). It is acknowledged that people have historically struggled with microorganisms, especially bacteria, which has led to severe sickness and fatalities in numerous cultural communities across the world (Smolinski et al., 2003). The antibiotic penicillin was the initially developed and most successful antimicrobial drug used to treat a variety of infectious disorders in the early 1940s. Nevertheless, the bacteria have started to develop mechanisms of resistance due to misuse, which has reduced the efficiency of penicillin (Singh et al., 2024). Antimicrobial resistance develops when an animal's or human's immune systems are unable to combat bacteria, viruses, parasites, insects, or other microbes (Moo et al., 2020). Antimicrobial resistance has been regarded as a remarkable biological phenomenon that develops gradually over time due to bacterial genetic change—however, factors like drug abuse and overuse speed up this process. Underprivileged parameters are control of antimicrobial medications, unsatisfactory observing the appearance of AMR, and inadequate quality checks for antibiotics. In developing countries, some factors of AMR have been distinguished (Mudenda et al., 2023). AMR is a naturally occurring phenomenon that results from bacterial adaptation over time after exposure to antimicrobials. Antimicrobial resistance has four different types of mechanisms: (1) energetic drug discharge, (2) drug target change, (3) inactivating a drug, and (4) decreasing intake of drugs. On the other hand, because of structural differences, Gram-positive and Gram-negative bacteria employ varying types of processes (Abushaheen et al., 2020).

Due to the exponential rise in AMR infections and a shortage of novel antimicrobial drugs to combat this problem, AMR—often referred to as the "Silent Pandemic"—has become one of the most important worldwide issues of the 21st century (Gupta & Srinivasan, 2022). AMR's rapid rise has led to ongoing research on its infection and fatality rates. Between 2018 and 2019, the UK's estimated AMR infection rate grew from 61,946 patients to 65,162 people (Tang et al., 2023). Antimicrobial resistance (AMR) prevalence rates in the EU exclusively exceeded 670,000 incidents annually, according to data collected by the European Centre for Disease Prevention and Control (ECDC) (Almutairy, 2024). Approximately 8·9 million deaths in 2019 were caused by bacterial infections, 1·27 million by antimicrobial resistance, according to a worldwide analysis of the effect of bacterial AMR (Naghavi et al., 2024). By 2050, the proportional death rate is projected to be 0.022 million in Oceania, 4.73 million in Asia, 4.15 million in Africa, 0.39 million in Europe, 0.392 million in South America, and 0.317 million in North America (Fongang et al., 2023).

AMR is associated with the health of livestock, humans, and the natural environment because of the uncaring, also overuse of antibiotics in different fields (animals, medicines, agriculture, and humans). Bacteria that are subjected to antimicrobial selection develop mobile genetic elements and resistance genes that can infect other bacteria of the same or different genus. Antimicrobial-resistant bacteria are also more adept at multiplying in human beings, livestock, and surroundings (Mancuso et al., 2021). Waste from agriculture, environmental contaminants, inadequate infection management, overuse of antibiotics, and the migration of animals and humans carrying resistant microbes all contribute to the propagation of adaptation (Endale et al., 2023). The One Health strategy must incorporate an interdisciplinary analysis of AMR because it is a complex issue (Calvo-Villamañán et al., 2023). Animal species, the environment, and human well-being are all impacted by AMR and are a significant global concern (Figure 1).

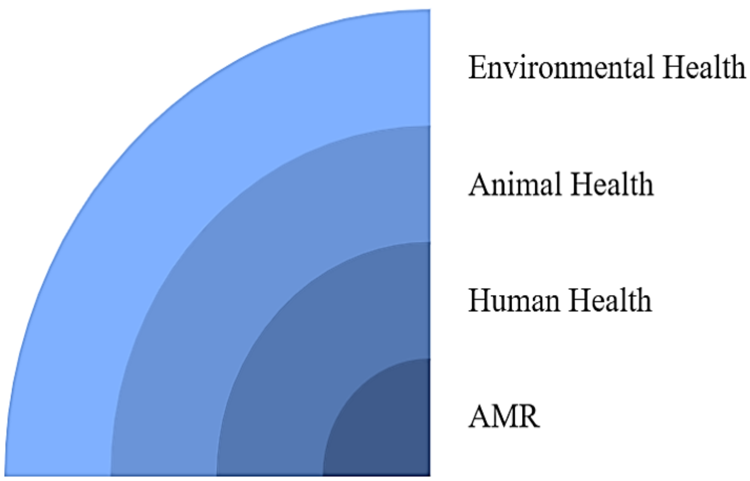

Fig. 1: One Health Approach to AMR (Biorender)

In response to AMR, many nations and international health organizations have taken action. To ensure that each agency works within its field of specialty and with other agencies to minimize the potential negative impacts of AMR, the "One Health Approach" was implemented. This demands a global collaborative approach involving multiple disciplines, including the Food and Agriculture Organization of the UN (FAO) and the World Organization of Animal Health (OIE) (Prata et al., 2022). Furthermore, to continuously close knowledge gaps and accomplish the objectives of the Global Action Plan for Controlling AMR (GAP-AMR), the World Health Organization (WHO) created the Global Antimicrobial Resistance and Use Surveillance System (GLASS) (World Health, 2021). By highlighting the serious risks to human and animal health, highlighting the multisectoral and interrelated nature of the problem, and presenting One Health approaches to antimicrobial resistance mitigation, particularly globally, this chapter offers a One Health perspective regarding the problem.

The One Health Approach

Several professions working together to address environmental, animal, and human health challenges is known as the "One Health" idea (Agarwal et al., 2024). The concept of One Health has ancient foundations and is based on the knowledge that humans and other creatures constitute several infectious illnesses, are interconnected, and reside in their identical ecosystems (Pitt & Gunn, 2024). According to some estimates, up to 75% of infectious diseases that have affected humans and emerged in recent decades are zoonotic, meaning they have animal origins (Rahman et al., 2020). Veterinarian Calvin Schwabe coined the phrase "One Medicine" to draw emphasis on the many parallels between human and animal medicine and to recognize that most treatments for animals have the potential to strengthen human wellness. Medical pioneers Rudolf Virchow and William Osler recognized the value of a comparative perspective to studies in medicine (Bresalier et al., 2021). The origins of AMR and the dynamics of multi-drug resistance pathogen transmission fall under One Health case studies, indicating that environmental, animal, and human professionals must work together to prevent global AMR (Aslam et al., 2021). The problems of antimicrobial resistance that emerge when identical forms of medications are used in people and animals are shown by the following examples.

Humans and animals have been using the highly bactericidal antibiotic colistin (polymyxin B) for decades, however, systemic administration of this medication results in nephrotoxicity (Mirjalili et al., 2022). This antibiotic is only used to treat patients with cystic fibrosis or skin infections (Millar et al., 2021). The incidence of systemic colistin management has been increased to treat contagions brought on by bacteria that are resistant to carbapenem (such as Escherichia coli and Pseudomonas aeruginosa) (Gogry et al., 2021). In some countries, colistin is overused, especially as a growth enhancer in animals, however, methods vary widely. Colistin resistance was first chromosomally encoded, however in 2015, it was discovered that E. coli strains recovered from food, animal, and blood cultures in China were colistin-resistant due to the plasmid-mediated mcr-1 gene (Shen et al., 2020). Colistin resistance is a sign that using large dosages of antibiotics to cure illnesses or promote growth can further create resistance (Andrade et al., 2020).

Fluoroquinolones are a broad-spectrum drug family that works against various Gram-negative and Gram-positive bacteria and are used to treat respirational and urinary tract infections (Bhatt & Chatterjee, 2022). Fluoroquinolone resistance can result from changes to DNA gyrase and topoisomerase IV target sites, loss of porins, or the existence of effluence pumps (Bush et al., 2020). In 1998, the first description of resistance to quinolones administered horizontally appeared. This resistance is caused by the qnr gene, which is found in a mobile genetic element. Fluoroquinolone resistance has been observed in poultry treated with Campylobacter jejuni strains (Velazquez-Meza et al., 2022). Humans may be exposed to these drug-resistant bacteria through the environment or the animal food chain (Serwecińska, 2020).

Strategies of One Health for Fighting Antimicrobial Resistance

WHO and other world organizations (including the Food and Agriculture Organization [FAO], OIE), along with many individual countries, have developed extensive action plans for addressing the antimicrobial resistance challenge. While creating their national strategies, participating countries are encouraged by the WHO Global Action Plan to implement a One Health approach to tackle antibiotic resistance (Mudenda et al., 2023). The following paragraphs discuss the five main goals that the WHO Global Action Plan seeks to accomplish. The WHO Global Action Plan goals are important to effectively fight antimicrobial resistance (Figure 2).

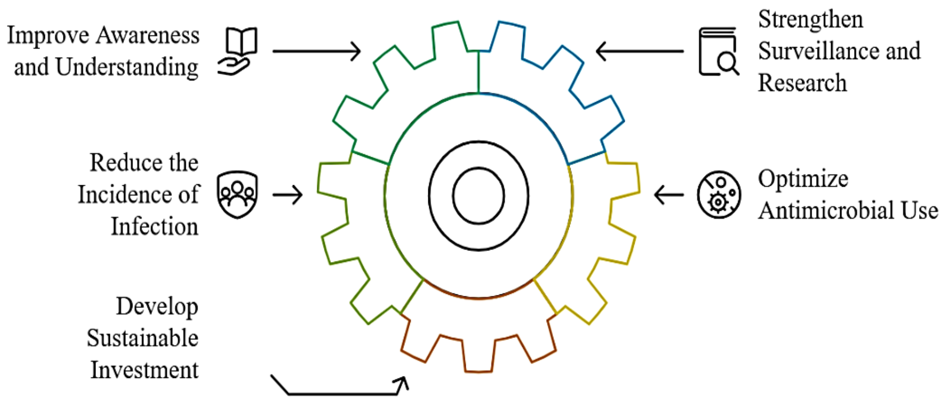

Fig. 2: WHO Global Action Plan Overview (Biorender)

Developing Understanding and Awareness of Antimicrobial Resistance

Lack of awareness and knowledge about AMR is among the primary causes of the improper use of antibiotics (Fuller et al., 2023). According to a recent Asian survey, the majority of Asian nations lack sufficient awareness among the general public and medical professionals regarding AMR and the proper use of antibiotics (Gandra et al., 2020). Everyone should, at the very least, be aware of the fundamentals of good sanitation to stop the spread of contagions, comprehend the importance of adhering to the treatment recommendations of the antimicrobial prescriber, and possess a fundamental awareness of the dangers utilizing antibiotics can cause to others as well as to oneself. This relates to the consumption of antibiotics by animals as well as humans. Greater awareness of the One Health components of antibiotic resistance is beneficial for all, but it is especially important for agriculture, veterinary technicians, domestic livestock owners, and those involved in the field of food manufacturing and the larger food industry (Golding, 2020). These categories have distinct understanding capabilities. Animal owners should be conscious that specific bacteria can be transmitted from humans to animals, and they must follow the guidance of their veterinarians when related to using pharmaceuticals and preventing an outbreak of sickness (Scarborough et al., 2021).

Farmers have to understand ways to grow vegetables, fruits, and livestock that require minimal use of antibiotics; possibly, they should only be used for dealing with medically unwell animals (Miller et al., 2022). Moreover, they require an understanding of strategies to improve fundamental livestock management to mitigate crowded, polluted, and stressful settings that promote the propagation of diseases in animal and plant populations to reduce the requirement for antimicrobial therapies (Endale et al., 2023). Veterinarians who administer antibiotics and advise farmers on preventive measures need a better understanding regarding the One Health component of antimicrobial resistance (Diskin, 2021). For the sake of their patient's well-being and fitness, their clients' economic interests, and the wellness of people everywhere, veterinarians need to demonstrate the expertise, perspectives, and behaviors that characterize good antimicrobial stewardship (Endale et al., 2023). The human healthcare community would also benefit from greater awareness and utilization of the biological processes that help control the propagation of pathogenic organisms, including antibiotic-resistant bacteria, such as prevention of infection, enhanced cleanliness, more effective sanitation, etc., as well as extensive knowledge of the One Health components of antimicrobial resistance. To reduce their impact on the choice and emergence of antibiotic resistance, health workers should be educated to understand the changeable mechanisms of antimicrobial resistance (Irfan et al., 2022). A method to increase awareness and understanding of the One Health features of antimicrobial resistance is through the wellness and illness preservation initiatives implemented by public health and animal health organizations, awareness-raising advertisements for consumers and livestock owners, agriculturalist outreach projects, animal welfare assessments, cultivating land industry publications for cultivators, the livestock industry educational programs, and continuing education opportunities for medical professionals and healthcare providers (McEwen & Collignon, 2018).

Strengthen Surveillance and Research

Research and surveillance are important because they detect issues with antibiotic resistance and provide solutions (Aggarwal et al., 2024). Antimicrobial resistance and application of antibiotics in human and primate domains need to be monitored at the national, regional, and international levels to determine the amount, development, and wellness consequences of susceptibility. Antimicrobial resistance trends that are clinically significant for both people and animals should be detectable by such surveillance. Antimicrobial use policies, antimicrobial stewardship initiatives, and Awareness should be given in every aspect of education arrangements to mitigate antimicrobial resistance (Majumder et al., 2020). Supervision is also necessary to evaluate the effectiveness of treatments and other methods for reducing antibiotic resistance. One Health monitoring of antimicrobial resistance ought to incorporate measurement of appropriate pathogens from specimens collected in a range of different animal, human, and ecological settings, including medical centers, extended-care and community-based veterinary centers, agricultural land, nourishment, and the natural world (such as biodiversity, the ground, and water) (Velazquez-Meza et al., 2022). Additionally, monitoring of antibiotic consumption should be conducted in human beings, animal welfare, and agricultural scenarios. To facilitate cross-country comparisons, it should also include national estimates of antimicrobial consumption in both human and animal species, as well as suitable factors (such as the size of the population, livestock population, and PCUs). To generate data that aid in assessing and guiding prescription practices and antibiotic use behaviors, antibiotic use analysis should also take place at the administering level (e.g., hospitals, communities, veterinary clinics, and farms) (Eltholth et al., 2022). Reports should be timely so that relevant parties can benefit from the integrated analysis, interpretation, and presentation of surveillance data across regions. WHO has released guidelines on coordinated, incorporated monitoring of antimicrobial resistance and antibiotic usage to assist advanced and emerging nations in implementing their national monitoring initiatives and to help improve worldwide surveillance activities, which are essential for enhanced collaboration of globally coordinated attempts to mitigate antimicrobial application (Iskandar et al., 2021).

Focused studies are necessary to show how resistance arises and spreads among and among bacterial species and ecological niches, including pathogens, environmental bacteria, and intestinal microbes (Wallace et al., 2020). To reduce the use of antibiotics in animals, additional investigation is needed to identify suitable, cost-effective substitutes for antimicrobials to avoid outbreaks of disease and to increase the productivity of development and manufacturing. More research is needed on improved techniques for diagnosis, procedures to improve utilization of antibiotics and prescription methods, and improved vaccines to support the management of antimicrobial agents (Majumder et al., 2020).

Reduce the Incidence of Infection

One well-known and crucial strategy to stop the emergence of antibiotic resistance in people is infection control in healthcare environments, especially in hospitals (Church & McKillip, 2021). In veterinary clinics, the use of formal infection control programs is not enough. Biosecurity and other disease control techniques are essential to preventing infections at the agricultural level in most food livestock firms, particularly for large-scale farming in the poultry and pork industries.

Controlling environmental contamination from the pharmaceutical sector and improving the safety of food and water for consumption, particularly in developing countries, are also essential to reducing the possibility that antimicrobial resistance could propagate from biological sources and pathways to humans (Milijasevic et al., 2024). Strategies to reduce foodborne pathogens at the farm and other manufacturing levels are necessary to limit the spread of enteric bacteria, such as Salmonella and Campylobacter, to humans. Similarly, reducing exposure to ambient bacteria and avoiding the indirect transmission of enteric bacteria (both susceptibility and resistant) from person to person depend on actions to improve the microbiological integrity of water for consumption and proper sewage treatment (Wen et al., 2020).

Maximise Antimicrobial Drug Use for Human and Animal Health

The first and most fundamental step in preventing and controlling AMR is the right use of antibiotics, as their abuse or misuse is the primary cause of AMR's beginning (Kewalramani & Chandi, 2021). The proper use of the available antibiotics is crucial because there have not been many new ones developed in recent decades.

One crucial strategy for combating antibiotic resistance is drug classification. According to the One Health viewpoint, the most significant categorization systems are those that classify antimicrobials according to how crucial they are to the health of humans and animals. Three categories of antimicrobials used in humans have been identified by established by WHO: critically important, highly important, and important (Table 1). Since its introduction in 2005, this system has gone through frequent updates. The classification aims to help regulate strategies for risk management to stop and control the development of antibiotic resistance in food animals. The highest-priority classes include quinolones and cephalosporins of the third and fourth generations (Abushaheen et al., 2020).

A system of categories for antimicrobials vital to animal health has been developed by the OIE. The list was first authorized by the OIE in 2007 and underwent revisions in 2013 and 2015. It made use of information obtained from an investigation of OIE member nations. There are several similarities between the WHO and OIE lists. For instance, macrolides, fluoroquinolones, and third- and fourth-generation cephalosporins are all included in the highly significant grouping of antimicrobials on both charts (Velazquez-Meza et al., 2022). A few countries, including the US and Canada, as well as the European Union, have developed their systems for categorising antimicrobial classes based on their importance to human health. In terms of human health, it is advantageous to standardise the criteria used in these various antimicrobial classifications and to advance the management of the intersection between the classifications for humans and animals.

This antimicrobial classification can be included in antimicrobial risk management plans in several ways. For example, antimicrobial drugs designated as therapeutically relevant (i.e., crucial, extremely important, or vital on the WHO criteria) is expected ceased to be employed to promote growth. This method is now being utilised in other countries (including the US and Canada) and is currently used in Korea and the European Union (EU) (Hu et al., 2021). Prohibiting the use of some microorganisms that are essential to human health in animals is an additional strategy. For instance, carbapenems, glycopeptides, monobactams, and some other types are authorised for use in companion animals under specific circumstances in the European Union; they are not permitted for use in food animal species or illegally in these categories of animals (Caneschi et al., 2023). Categorization can also be applied to formularies or treatment cascade schemes (e.g., first-line, alternatives (second-line, etc.). Because of their importance to human health, the European Union, for example, requires that fluoroquinolones and third- and fourth-generation cephalosporins be used only when no other antibacterial agents are licensed for targeted different species and applications. A different use of antimicrobial taxonomy is the industry's encouragement of monitoring antimicrobial use (Patel et al., 2020).

Table 1: The importance of antibiotic classes for both human and animal health is categorized (McEwen & Collignon, 2018)

Category	Human Health (WHO)	Animal Health (OIE)
Critically Important	Phosphonic acid derivatives, aminoglycosides, ansamycins, carbapenems and other penems, third and fourth generation cephalosporins, Monobactams, Oxazolidinones, Glycopeptides, Glycylcyclines, Lipopeptides, Macrolides and Ketolides, Penicillins (organic, aminopenicillins, and antipseudomonal), Polymyxins, Quinolones, pharmaceuticals only used to treat mycobacterial illnesses like TB. The significance of antibiotic classes for the well-being of humans and animals is categorised.	Cephalosporins (third and fourth generation), aminoglycosides, amphenicols, macrolides, the antibiotics penicillin (authentic, aminopenicillins, aminopenicillins with beta-lactic acid inhibitory agents, antistaphylococcal), fluoroscopic antibiotics sulfonamides, diphenopyrimidines, and tetracyclines
Highly Important	steroids antibacterial medications, Streptogramins, Sulfonamides, Dihydrofolate enzyme inhibitors, Pleuromutilins, Pseudomonic acids, Riminofenazines, Amphenicols, Cephalosporins (first & second generation), or Cephamycins, Lincosamides, and Penicillins (antistaphylococcal), Tetracycline derivative	First-generation quinolones (flumequin, miloxacin, nalidixic acid, oxolinic acid), ionophores, lincosamides, phosphoric acid, pleuromutilins, polymyxins (which comprises bacitracin along with additional polypeptides), rifamycins, and cephalosporins (first and second generation) are examples of ansamycin.
Important	Cyclic polypeptides, nitrofurantoins, nitroimidazoles, and aminocyclitols	Thiostrepton, Arsenical, Fusidic acid, Bicyclomycin, Orthosomycins, Quinoxalines, Streptogramins, along with Aminocoumarin

Develop Sustainable Investment in Interventions

Interventions in the welfare of animals that reduce the consumption of antibiotics, such as increased vaccines and other nonantimicrobial disease management measures, are also required, even though the stated purpose of the WHO Global Action Plan is mostly orientated on human health (Mudenda et al., 2023). Vaccination can lower the danger of emerging antimicrobial resistance (AMR) in bacterial pathogens and decrease the need for antibiotics. Meninges, Salmonella pneumoniae, Haemophilus influenzae, particularly type B, diarrhoea, TB, tetanus, malaria, pertussis, and typhoid fever belong to bacterial ailments that have been successfully controlled using vaccinations. The most significant instance of a bacterial vaccine that can reduce the frequency of pneumococcal infections and, consequently, the occurrence of antimicrobial resistance (AMR) in S. pneumoniae is the pneumococcal conjugate vaccine (PCV) (Reyburn et al., 2023).

The Difficulties of Combating Antimicrobial Overuse

There are many obstacles in the way of improving the management of antibiotics in animals as well as humans (Mudenda et al., 2023). These consist of the fact that numerous nations lack monitoring and regulation over the accessibility of antibacterial medications, that patients and animal owners push for the intake of antibiotics even when they don't require them, and that there is insufficient drive for change and knowledge that all pharmacists and users need to be good antimicrobial stewards (Scott). Other barriers to antimicrobial stewardship include the deficiency of administration on the non-prescription distribution of antibiotics for usage in humans and animals in various countries, especially in developing countries. This fundamental information must be established immediately to inform future planning and action focused on preventing the spread of AMR (Porter et al., 2021).

Conclusion

The threat of AMR to world health demands immediate and sustained action in the fields of humans, animals, and the environment. The drug abuse and overuse, unsatisfactory observing the appearance of AMR, and inadequate quality checks for antibiotics are the parameters which speed up the process of devolping AMR. Promoting a coordinated and interdisciplinary One Health approach is necessary to lower the risks to human, animal, and environmental health due to the global originating and spread of AMR. The global assessment of one health strategy helps in AMR prevention through improving public awareness, strengthening surveillance, and infection control measures, responsible use of antimicrobials, and sustainable investments in vaccinations and other interventions. The WHO have developed action plans for addressing the antimicrobial resistance challenge and encourages the participating countries to create their own national action plan. The WHO action plans require interdisciplinary efforts from all sectors to fight against the globally spreading antimicrobial resistance.

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