Emerging Public Health Issues Originating from Antimicrobial Resistance (AMR)

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Abstract

Antibiotic discovery is regarded as a major medical accomplishment of the 20th century. This development initially held up the promise of a revolution in the treatment of bacterial infections, antibiotic-resistant bacteria gradually emerged as a result of the extensive and occasionally misused use of antibiotics. Now problem of drug-resistant microorganisms has grown to be a major worldwide public health issue. National and international organizations have emphasized the urgent need for action on antimicrobial resistance (AMR), which has been identified as one of the main dangers to individual and public health in the twenty-first century. One of the biggest concerns in healthcare organization is bacterial resistance. Antimicrobial resistance (AMR) has become a persistent public health issue worldwide, with 10 million deaths annually predicted by 2050. The primary risk factors for the emergence of antibiotic resistance are antibiotic overuse and abuse. AMR has been rising since COVID-19 patients were treated with antibiotics. A multimodal strategy to stop the emergence of antibiotic resistance must include antimicrobial stewardship. Optimizing antimicrobial treatment and reducing antimicrobial resistance are two benefits of antimicrobial stewardship. The Global Action Plan focusing on AMR (GAP-AMR) is a management program connected to AMR that was introduced by the WHO. The WHO has stated that AMR affects seven of the 17 Sustainable Development Goals (SDGs), particularly in terms of environmental, social, and economic targets in the SDG framework. The development of new, efficient antibiotics or the reduction of unnecessary antibiotic use are potential solutions to the growing issue of AMR.

Keywords: AMR, Global Action Plan, Sustainable Development Goals, Public health, Antibiotics

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Introduction

Microbes, particularly bacteria, have always been a problem for humans, causing significant illness and death in a variety of human populations around the globe (Abushaheen et al., 2020). Beginning with the use of sulfonamides in the 1930s, penicillin and streptomycin were introduced in the 1940s, and broad-spectrum bacteriostatic antibiotics were produced in the 1950s. Antibiotic discovery is regarded as a major medical accomplishment of the 20th century. In the 1960s, bactericidal antibiotics, synthetic compounds, and particular narrow-spectrum antibiotics emerged in the following decades. Although these developments initially held up the promise of a revolution in the treatment of bacterial infections, antibiotic-resistant bacteria gradually emerged as a result of the extensive and occasionally misused use of antibiotics. The problem of drug-resistant microorganisms has grown to be a major worldwide public health issue (Deori et al., 2024).

When bacteria, viruses, fungi, and parasites develop the ability to withstand the effects of drugs that once effectively killed or suppressed them, this is known as antimicrobial resistance (AMR). Although this is a normal evolutionary process, the overuse and abuse of antibiotics in agriculture and human medicine has significantly expedited it. AMR is a developing public health emergency that has significant ramifications for communities, economy, and health systems around the world. National and international organizations have emphasized the urgent need for action on antimicrobial resistance (AMR), which has been identified as one of the main dangers to individual and public health in the twenty-first century. AMR is a complicated, multifaceted worldwide challenge rather than just an issue that results from the difficulties in treating infectious diseases. Current and future populations are at a significant risk of harm, loss, and death due to AMR (Littmann & Viens, 2015). When microbes develop resistance to current medications, there are fewer options for treatment, which raises fatality rates, lengthens sickness duration's, and increases healthcare expenses. It hampers procedures that depend on efficient infection prevention and treatment, such as organ transplants, cancer therapies, operations, and the care of preterm infants.

Types of Antimicrobial Resistance

Antimicrobial agents come in a variety of forms, including antibiotics, disinfectants, and food preservatives. They can be used to stop bacteria from growing, stop them from multiplying, or even kill them (Abushaheen et al., 2020). Antimicrobial resistance is classified into various kinds according to the particular diseases and drug classes that they are resistant to:

Bacterial Resistance

Antibiotic resistance and bacterial resistance are frequently linked. Examples of this include methicillin-resistant Staphylococcus aureus (MRSA). One of the biggest concerns in healthcare organization is bacterial resistance. A greater chance for bacteria to develop more complex resistance to antibiotics is presented by the increased use of antibiotics worldwide (Abushaheen et al., 2020).

Antiviral Resistance

Viruses such as influenza and HIV exhibit antiviral resistance, where mutations hinder the effectiveness of antiviral medications.

Antifungal and Antiprotozoal Resistance

New developments in the management of protozoal and fungal infections.

Genetic Mechanisms of AMR

Antibiotics, typically administered by injection or oral tablet, are widely used to treat infections in both humans and animals. Bacteria can acquire antimicrobial resistance (AMR) in a number of ways, such as plasmid-mediated horizontal gene transfer (HGT) and mutation during DNA replication.

Mutation

AMR can evolve quickly through point mutations in chromosomal DNA genes, and in vitro studies have demonstrated that bacterial cells can develop mutations that allow them to withstand ten times the initial dosage of an antibiotic. A resistant population may spread clonally as a result of repeated exposure to an antibiotic. Fluoroquinolone resistance linked to point mutations in the genes encoding DNA gyrase (gyrA and gyrB) and Topoisomerase IV (parC and parE) is one such instance in *E. coli* (Roberts et al., 2021).

Horizontal gene Transfer (HGT)

The ineffectiveness of antibiotics against an increasing number of bacterial diseases is becoming a global health problem. Although the transmission dynamics of genes conferring antibiotic resistance are poorly understood, horizontal gene transfer (HGT) plays a crucial role in the rapid emergence of resistance. Several HGT processes free genes from typical vertical inheritance. Plasmid conjugation, bacteriophage transduction, and extracellular DNA transformation all enable genetic material to move between strains and species. Because an antibiotic resistance gene (ARG) can spread resistance to several unrelated infections, it can be the cause of an outbreak, adding a significant dimension to infectious disease (Lerminiaux & Cameron, 2018). One of the main factors contributing to the persistence of an AMR population is the use of antibiotics; other substances, such as heavy metals, biocides, and disinfectants, can also serve as AMR population drivers by co-selecting for related genes; however, eliminating the driver does not always mean that a resistant population will vanish (Roberts et al., 2021).

Global Overview of AMR

Antimicrobial resistance (AMR) has become a persistent public health issue worldwide, with 10 million deaths annually predicted by 2050. In humans and animals, antimicrobial resistance (AMR) arises when bacteria, fungi, viruses, and parasites do not react to antimicrobial treatments, allowing the microorganism to survive inside the host. Increasing the worldwide burden of antimicrobial resistance, the overuse and misuse of antibiotics, especially their improper use, continues to be the main cause of the current crisis. Antibiotic use and consumption around the world are thus constantly being rigorously watched (Tang et al., 2023). Infectious diseases are becoming more commonplace worldwide, especially in low- and middle-income nations and among vulnerable groups.The viability of health systems around the world and the efficacy of treatment for these illnesses are seriously endangered by AMR (Jee et al., 2018). In order to fill in knowledge gaps and create new antibiotics, diagnostics, and preventative measures, as well as to guide strategies to reduce the spread of drug-resistant bacteria and resistance, basic microbiological research is essential (Mattar et al., 2020).

Causes and Drivers of AMR

Overuse and Misuse of Antimicrobials

The primary risk factors for the emergence of antibiotic resistance are antibiotic overuse and abuse. The issues linked to antibiotic resistance may escalate if medical professionals lack the necessary professional skills. While antibiotic resistance is a worldwide problem, Asia is particularly affected because the most potent medications are easily accessible there without a prescription or a diagnosis. Antibiotics' high efficiency and ease of access cause overuse and misuse, which in turn promotes the development of bacterial resistance (Mittal et al., 2020). Greece has a high rate of antibiotic resistance, which is largely caused by overuse of antibiotics in both the population and hospitals. The issue is exacerbated by both people self-medicating and doctors over-prescribing antibiotics (Karakonstantis & Kalemaki, 2019).

Agricultural Use of Antimicrobials

Antimicrobial resistance, or AMR, is a worldwide health crisis that affects both people and animals and reduces the efficacy of drugs used to treat diseases. The use of antibiotics carelessly and its role in AMR have drawn more attention to the agri-food industry (McKernan et al., 2021). In order to encourage development and boost feed efficiency, or to avoid disease, the majority of applications include adding small amounts of antimicrobial agents to the diet of healthy animals over an extended period of time. These non-therapeutic applications lead to resistance and novel health risks for people (Paulson et al., 2015).

Inadequate Infection Control Practices

Hospital cleanliness failures, selective pressures from antibiotic misuse, and mobile genetic elements that might encode bacterial resistance mechanisms are the main causes of antimicrobial-drug resistance in hospitals (Weinstein, 2001). Globally, healthcare-associated infections (HAIs) are among the most important public health issues. Hospital surfaces including bed bars and headers, bedside tables, taps, and ward knobs that come into direct touch with patients are thought to be easily contaminable and potentially dangerous for spreading infections to patients (Facciolà et al., 2019).

Environmental Factors

The emergence and spread of antimicrobial resistance are caused by environmental factors, such as naturally occurring resistance genes, inappropriate disposal of unused antimicrobial s, contamination from agricultural and sanitation chemicals, waste in public areas, animal farms, and pharmaceutical industries (Endale et al., 2023). The emergence and dissemination of antibiotic resistances seem to be significantly influenced by freshwater, underscoring the need for water quality improvement measures (Lupo et al., 2012). The introduction of antibiotics into the environment through wastewater may hasten the development of bacteria and resistance genes in the surrounding environment. (Hsu et al., 2014)

Global Travel and Trade

International borders don't matter to resistant bacteria. By travelling between medical facilities with wildly disparate AMR rates, medical tourists run the risk of spreading extremely resistant strains (Frost et al., 2019). Antimicrobial-resistant diseases that impact both industrialized and developing nations are generated and disseminated in large part through travel, trade, tourism, and mass population migration (Memish et al., 2003).

Emerging Pathogens and AMR Threats

Emerging infections that represent major risks to public health are a result of AMR's ongoing evolution. These include completely new resistant infections that are challenging to treat with current treatments, as well as multi drug-resistant organisms (MDROs) that are resistant to multiple classes of antibiotics.

Multi drug-Resistant Organisms (MDROs)

The term "MDROs" refers to microorganisms, primarily bacteria, that exhibit resistance to one or more antimicrobial agent classes (Siegel et al., 2007). Multidrug-resistant organisms pose a serious risk to public health, including vancomycin-resistant enterococci (VRE), methicillin-resistant Staphylococcus aureus (MRSA), and multidrug-resistant gram-negative bacteria. illnesses brought on by multidrug-resistant organisms are linked to significant morbidity and mortality; in the US, they result in about 2 million illnesses and 23,000 fatalities annually, with an additional $20 billion in costs.Patients receiving maintenance haemodialysis are especially vulnerable to multidrug-resistant pathogens (D'Agata, 2018). One significant human pathogen is S. aureus. Additionally, it is among the bacteria that are most resistant to antibacterial medications. The quick dissemination of clones, which are marked by increased virulence and resistance to numerous antibiotics, is one of these bacteria's distinctive traits (Mlynarczyk-Bonikowska et al., 2022). Staphylococci can be effectively combatted by penicillin and its derivatives. However, penicillin-resistant, penicillinase-containing S. aureus strains quickly proliferated globally following the therapeutic introduction of penicillin. In 1959, the penicillinase-resistant penicillin derivative methicillin was created in response to the fact that penicillin was no longer effective against many pathogenic strains of *S. aureus* (Otto, 2013). Since the 1960s, methicillin-resistant Staphylococcus aureus (MRSA) has been a major cause of bacterial infections in both community and healthcare settings, spreading around the world (Lee et al., 2018); its colonisation rates range from 3.9% to 32%, so it is one of the most important nosocomial pathogens, is especially concerning for infections in neonates. MRSA is likely to be contracted in a hospital setting through the birth canal and/or through contact with parents, medical personnel, patients, or contaminated hospital surroundings (Chew et al., 2023). Another important medical and public health concern is Vancomycin-resistant Enterococci (VRE), which are linked to prolonged colonisation and dangerous multidrug-resistant infections (Ahmed & Baptiste, 2017). In the middle of the 1980s, vancomycin-resistant enterococci (VRE) were discovered to be hospital-associated infections in Europe, and they have since spread quickly throughout the world. Through direct contact with colonised or infected patients, indirect contact through healthcare personnel' hands, contaminated patient care equipment, or ambient surfaces, vancomycin-resistant enterococci (VRE) can be spread (Tacconelli & Cataldo, 2008).

Emerging Superbugs

According to Chuanchuen (2011) "Superbug" or "super bacterium" are colloquial terms for bacterial strains that are extremely resistant to practically all known antibiotics, suggesting that they are super fighters against antimicrobial drugs. While bacteria may be benign and occasionally beneficial, superbugs are primarily pathogenic bacterial strains, and infections with them typically lead to greater fatality rates, longer hospital stays, more severe illnesses, and higher treatment costs. Because superbugs are so skilled, they can develop or acquire resistance to the majority of antimicrobials on the market, including new medications intended to treat germs that have already developed resistance to medications from previous generations, and then grow stronger. A combination of rising resistance, careless use, and a lack of new antibiotic discovery has resulted in the rise of highly resistant superbugs and DS microorganisms that cause higher rates of morbidity and mortality (Casey, 2012).

AMR in Pandemics

More and more research shows that AMR has been rising since COVID-19 patients were treated with antibiotics. It is critical to investigate the prevalence of AMR in COVID-19 patients. There is ample evidence that excessive use of antibiotics by humans has resulted in resistant microorganisms that negatively impact human health; in fact, AMR is ranked among the top ten list of potential worldwide hazards to food security, human health, and development (Rehman, 2023).

Public Health Impact and Consequences of AMR

AMR has serious repercussions for public health, impacting healthcare expenses, morbidity, and mortality.

Increased Mortality and Morbidity

Increasing mortality and morbidity, lengthening hospital stays, and driving up health care expenses are all potential outcomes of the current trend of rising AMR. By 2050, the predicted worldwide mortality rate from AMR might rise to 10 million deaths year, a significant increase from the present estimated 700,000 deaths annually. More than fifty years of AMR history changed course in 2014, when it went from being a technical problem to a political priority (Inoue, 2019).

Economic Burden

When comparing patients with infections caused by antimicrobial-resistant organisms to those without, the cost difference is even more pronounced. Patients with infections caused by antimicrobial-resistant organisms incur higher costs (US$6000–30,000) than patients with infections caused by antimicrobial-susceptible organisms. Knowing the clinical and financial effects of antibiotic-resistant bacterial infections as well as the advantages of particular strategies aimed at lowering these infections would enable optimal control and enhanced patient safety, especially in light of tight budgets (Maragakis et al., 2008).

Impact on Medical Procedures

Antimicrobial resistance (AMR), which jeopardizes the effectiveness of antimicrobial medications in treating microbial illnesses, is a serious issue for modern medicine. Cancer patients are especially susceptible to infections and usually depend on antimicrobial medicines to cure these side effects because they are typically weakened by treatments like chemotherapy. However, this reliance on antimicrobial therapy is made more difficult by the growth of antibiotic resistance, which compromises the efficacy of these treatments. Evidence has demonstrated that AMR is impeding the efficient administration of cancer medicines, which will have negative effects (Lawal et al., 2024).

Global Health Disparities

Human health is still seriously threatened by the rising prevalence of antimicrobial resistance (AMR) worldwide. Around the world, the effects of AMR vary. The disproportionate impact is seen in low- and middle-income countries (LMICs), in part because of the high prevalence of infectious diseases (Sulis et al., 2021). In many low- and middle-income nations, the high prevalence of infectious diseases, poverty, inadequate health and governance systems, and low knowledge continue to be significant obstacles in the fight against AMR (Pokharel et al., 2019).

AMR and Healthcare Systems

Globally, healthcare systems are being severely strained by antimicrobial resistance (AMR), which jeopardizes the advancements in contemporary medicine and compromises the capacity to successfully treat infections. The overuse and misuse of antibiotics contributes to the persistence and spread of AMR, which poses a number of problems that impact how well healthcare systems operate.

Strain on Healthcare Resources

An international health concern that endangers people, animals, and the environment is antimicrobial resistance (AMR). There is mounting evidence that patient paths, healthcare environments, and infrastructure all play a part in sustaining and advancing AMR through both direct and indirect mechanisms (Cocker et al., 2024). Indeed, the hospital setting serves as a reservoir for possible viruses, which are constantly dispersed by medical staff, guests, and hospitalized patients (D'Accolti et al., 2019). Additionally, it has been demonstrated that using pediatrics antibiotics that had expired resulted in greater rates of resistance than using medications that had not expired. Utilizing outdated drugs actually increases resistance rates by 2–6 times when compared to utilizing unexpired medications. One of the primary causes of antibiotic resistance is most likely the accessibility of drugs. Since they are frequently available without a prescription from a doctor, self-medication and prescriptions from inexperienced healthcare professionals lead to the overuse of antibiotics. Antibiotics are widely accessible without a prescription from neighborhood pharmacies, hospitals, drugstores, roadside stands, and hawkers in many Asian, African, and Latin American nations (Sifri et al., 2019). A major factor in the emergence and spread of drug-resistant bacterial infections is the overuse of antibiotics, close patient-to-patient contact, and the requirement for improved hygiene and sanitation in hospitals. Research on new antibiotic drugs to treat infectious diseases is stalling, despite the evidence that antibiotic resistance is a major problem and a growing worldwide threat. Right now, the main reasons for this are a lack of financial incentives and regulatory barriers (Sifri et al., 2019).

Antibiotic Stewardship Programs

A multimodal strategy to stop the emergence of antibiotic resistance must include antimicrobial stewardship. Choosing the right medication and maximizing its dosage and duration to treat an infection while reducing toxicity and creating an environment that encourages the growth of resistant bacterial strains are all components of good antimicrobial stewardship (Fishman, 2006). Initiatives for hospital antimicrobial stewardship seek to maximize antibiotic prescriptions in order to improve patient care, save hospital costs, and slow the development of antibiotic resistance (MacDougall & Polk, 2005). Two advantages of antimicrobial stewardship are lowering antimicrobial resistance and improving antimicrobial treatment (Aina et al., 2024).

Barriers to Implementing Stewardship in Resource-Poor Settings

Among the obstacles encountered in these settings include limited access to medical facilities and personnel, poor diagnostic capabilities, a shortage of necessary medications, and challenges in putting infection prevention and control measures into practice (Amadi et al., 2024). AMS implementation in LMICs (Low to Middle Income Countries) faces numerous obstacles. Identifying politics that influence health decisions and exploring health inequality are essential to comprehending AMR and its drivers (Shamas et al., 2023).

Infection Prevention and Control Measures

The key to lowering the demand for antimicrobial use and preventing the development of antibiotic resistance is infection prevention and control, or IPC (Fleming, 2019). IPC has the potential to be one of the most economical ways to fight AMR. According to a new analysis from the Organization for Economic Co-operation and Development (OECD), encouraging basic IPC practices like hand cleanliness might cut the health impact of AMR by almost 40% (Lacotte et al., 2020).

Global Efforts to Address AMR

International Frameworks and Initiatives

The Global Action Plan focusing on AMR (GAP-AMR) is a management program connected to AMR that was introduced by the WHO. The goal of this strategy is to guarantee that infectious diseases can always be effectively treated and avoided by responsibly storing antimicrobials with suitable accessibility and quality controls. To achieve this goal, five primary goals were set, one of which is to improve the effectiveness of antimicrobial medicine use for the health of humans and animals. This would necessitate a strong regulatory framework (Tang et al., 2023).

Antimicrobial Resistance and the Sustainable Development Goals of the United Nations

According to Tang et al. (2023), the WHO has stated that AMR affects seven of the 17 Sustainable Development Goals (SDGs), particularly in terms of environmental, social, and economic targets in the SDG framework. The United Nations has produced 17 SDGs, including many aspects of societal and human interactions, as part of the 2030 Agenda for Sustainable Development. One SDG is SDG3—"Good Health and Wellbeing." AMR has a named specific inclusion within this SDG, with indicator 3.d.2, namely, "Percentage of bloodstream infections due to selected antimicrobial-resistant organisms."

Global Antimicrobial Resistance Surveillance System

The World Health Organization (WHO) introduced the global antimicrobial resistance monitoring system (GLASS) in 2015. When clinical specimens are sent to a microbiological lab for clinical use, GLASS serves as a surveillance system (Sirijatuphat et al., 2018). A vital instrument in the fight against AMR, AMS consists of a systematic series of activities that support and encourage the responsible use of antibiotics at the individual, national, and international levels, taking into account a number of factors like environmental concerns, animal health, and human health (Ajulo & Awosile, 2024).

Research and Development

The development of new, efficient antibiotics or the reduction of unnecessary antibiotic use are potential solutions to the growing issue of AMR. Vaccines can significantly lessen the need for antibiotics and seem to be the most promising substitutes for them in the treatment of a number of bacterial and viral illnesses (Gupta & Sharma, 2022).

Conclusion

In conclusion, the overuse and abuse of antibiotics in agriculture, animals, and humans has resulted in antimicrobial resistance (AMR), a serious worldwide health concern. Horizontal gene transfer (HGT) and mutation are the genetic mechanisms behind AMR. Because AMR increases mortality, morbidity, and healthcare expenditures, it presents serious public health challenges. Globally, infectious diseases are growing more prevalent, particularly among vulnerable populations and in low- and middle-income countries. The efficacy of existing medicines is under threat from the emergence of superbugs and multidrug-resistant organisms (MDROs), which could result in increased treatment expenses and longer hospital admissions. Inadequate infection control procedures, environmental contamination, international travel, and trade are some of the variables that contribute to the spread of AMR. Infection prevention and control strategies, antimicrobial stewardship programs, and international projects like the Global Action Plan on AMR are all part of the fight against AMR. New antibiotics and other therapies are being developed as part of continuous research and development to combat the escalating threat of AMR. Using antibiotics less and more sensibly are the best long-term solutions to this problem. To solve this pressing problem and ensure that antimicrobial therapies continue to be effective for upcoming generations, collaboration between governments, healthcare professionals, academics, and the general public is crucial.

References

Abushaheen, M. A., Muzaheed, N., Fatani, A. J., Alosaimi, M., Mansy, W., George, M., Acharya, S., Rathod, S., Divakar, D. D., Jhugroo, C., Vellappally, S., Khan, A. A., Shaik, J., & Jhugroo, P. (2020). Antimicrobial resistance, mechanisms and its clinical significance. *Disease-a-Month*, *66*(6), 100971. https://doi.org/10.1016/j.disamonth.2020.100971

Ahmed, M. O., & Baptiste, K. E. (2017). Vancomycin-Resistant Enterococci: A Review of Antimicrobial Resistance Mechanisms and Perspectives of Human and Animal Health. *Microbial Drug Resistance*, *24*(5), 590–606. https://doi.org/10.1089/mdr.2017.0147

Aina, B. A., Ismail, F. B., Adediran, O. E., Sheba, O. O., & Fasoyin, M. O. (2024). The importance of antimicrobial stewardship (AMS) in the mitigation of antimicrobial resistance (AMR). *West African Journal of Pharmacy*, *35*(2), 1-10.

Ajulo, S., & Awosile, B. (2024). Global antimicrobial resistance and use surveillance system (GLASS 2022): Investigating the relationship between antimicrobial resistance and antimicrobial consumption data across the participating countries. *PLoS ONE*, *19*(2), e0297921. https://doi.org/10.1371/journal.pone.0297921

Amadi, S. C., Daniel, F. M., Ikiroma, S., & Oboro, I. L. (2024). Antimicrobial Stewardship in Resource-Limited Settings. In *Pharmaceutical science*. https://doi.org/10.5772/intechopen.114057

Casey, G. (2012). Antibiotics and the rise of superbugs. *PubMed*, *18*(10), 20–24. https://pubmed.ncbi.nlm.nih.gov/23342855

Chew, C. H., Yeo, C. C., Hamzah, A. M. C., Al-Trad, E. I., Jones, S. U., Chua, K. H., & Puah, S. M. (2023). Multidrug-Resistant Methicillin-Resistant Staphylococcus aureus Associated with Hospitalized Newborn Infants. *Diagnostics*, *13*(6), 1050. https://doi.org/10.3390/diagnostics13061050

Chuanchuen, R. (2011). Emerging Drug-resistant Superbugs. *The Thai Journal of Veterinary Medicine*, *41*(1), 7–10. https://doi.org/10.56808/2985-1130.2282

Cocker, D., Birgand, G., Zhu, N., Rodriguez-Manzano, J., Ahmad, R., Jambo, K., Levin, A. S., & Holmes, A. (2024). Healthcare as a driver, reservoir and amplifier of antimicrobial resistance: opportunities for interventions. *Nature Reviews Microbiology*, *22*(10), 636–649. https://doi.org/10.1038/s41579-024-01076-4

D'Accolti, M., Soffritti, I., Mazzacane, S., & Caselli, E. (2019). Fighting AMR in the Healthcare Environment: Microbiome-Based Sanitation Approaches and Monitoring Tools. *International Journal of Molecular Sciences*, *20*(7), 1535. https://doi.org/10.3390/ijms20071535

D'Agata, E. M. (2018). Addressing the Problem of Multidrug-Resistant Organisms in Dialysis. *Clinical Journal of the American Society of Nephrology*, *13*(4), 666–668. https://doi.org/10.2215/cjn.13781217

Deori, C., Sonowal, T., & Das, M. (2024). Antimicrobial resistance: A looming threat to public health and global well-being. *Indian Journal of Community and Family Medicine*, *10*(1), 18–25. https://doi.org/10.4103/ijcfm.ijcfm_1_24

Endale, H., Mathewos, M., & Abdeta, D. (2023). Potential Causes of Spread of Antimicrobial Resistance and Preventive Measures in One Health Perspective-A Review. *Infection and Drug Resistance*, *16*, 7515–7545. https://doi.org/10.2147/idr.s428837

Facciolà, A., Pellicano, G. F., Visalli, G., Paolucci, I. A., VENANZI RULLO, E., Ceccarelli, M., & LA FAUCI, V. (2019). The role of the hospital environment in the healthcare-associated infections: a general review of the literature. *European Review for Medical & Pharmacological Sciences*, *23*(3).

Fishman, N. (2006). Antimicrobial stewardship. *American Journal of Infection Control*, *34*(5), S55–S63. https://doi.org/10.1016/j.ajic.2006.05.237

Fleming, N. (2019). AMR: effective infection prevention and control measures. *Practice Nursing*, *30*(8), 390–395. https://doi.org/10.12968/pnur.2019.30.8.390

Frost, I., Van Boeckel, T. P., Pires, J., Craig, J., & Laxminarayan, R. (2019). Global geographic trends in antimicrobial resistance: the role of international travel. *Journal of Travel Medicine*, *26*(8). https://doi.org/10.1093/jtm/taz036

Gupta, R., & Sharma, S. (2022). Role of alternatives to antibiotics in mitigating the antimicrobial resistance crisis. *The Indian Journal of Medical Research*, *156*(3), 464. https://doi.org/10.4103/ijmr.ijmr_3514_20

Hsu, J., Chen, C., Young, C., Chao, W., Li, M., Liu, Y., Lin, C., & Ying, C. (2014). Prevalence of sulfonamide-resistant bacteria, resistance genes and integron-associated horizontal gene transfer in natural water bodies and soils adjacent to a swine feedlot in northern Taiwan. *Journal of Hazardous Materials*, *277*, 34–43. https://doi.org/10.1016/j.jhazmat.2014.02.016

Inoue, H. (2019). Strategic approach for combating antimicrobial resistance (AMR). *Global Health & Medicine*, *1*(2), 61–64. https://doi.org/10.35772/ghm.2019.01026

Jee, Y., Carlson, J., Rafai, E., Musonda, K., Huong, T. T. G., Daza, P., Sattayawuthipong, W., & Yoon, T. (2018). Antimicrobial resistance: a threat to global health. *The Lancet Infectious Diseases*, *18*(9), 939–940. https://doi.org/10.1016/s1473-3099(18)30471-7

Karakonstantis, S., & Kalemaki, D. (2019). Antimicrobial overuse and misuse in the community in Greece and link to antimicrobial resistance using methicillin-resistant S. aureus as an example. *Journal of Infection and Public Health*, *12*(4), 460–464. https://doi.org/10.1016/j.jiph.2019.03.017

Lacotte, Y., Årdal, C., & Ploy, M. (2020). Infection prevention and control research priorities: what do we need to combat healthcare-associated infections and antimicrobial resistance? Results of a narrative literature review and survey analysis. *Antimicrobial Resistance and Infection Control*, *9*(1). https://doi.org/10.1186/s13756-020-00801-x

Lawal, O. P., Ahmed, N. K., Ilesanmi, T. A., Anthony, G. I., Nwosu, S. N., Ogungbemiro, F. O., Olaide, Z., Adeniyi, M. M., Okoye, U. L., Olufunmilayo, A. M., Christopher, A. A., & Oseghale, I. D. (2024). The Impact of Antimicrobial Resistance on Cancer Treatment: A Systematic Review of Current Evidence and Future Directions. *Asian Journal of Research in Medical and Pharmaceutical Sciences*, *13*(4), 9–27. https://doi.org/10.9734/ajrimps/2024/v13i4270

Lee, A. S., De Lencastre, H., Garau, J., Kluytmans, J., Malhotra-Kumar, S., Peschel, A., & Harbarth, S. (2018). Methicillin-resistant Staphylococcus aureus. *Nature Reviews Disease Primers*, *4*(1). https://doi.org/10.1038/nrdp.2018.33

Lerminiaux, N. A., & Cameron, A. D. (2018). Horizontal transfer of antibiotic resistance genes in clinical environments. *Canadian Journal of Microbiology*, *65*(1), 34–44. https://doi.org/10.1139/cjm-2018-0275

Littmann, J., & Viens, A. (2015). The ethical significance of antimicrobial resistance. *Public Health Ethics*, phv025. https://doi.org/10.1093/phe/phv025

Lupo, A., Coyne, S., & Berendonk, T. U. (2012). Origin and Evolution of Antibiotic Resistance: The Common Mechanisms of Emergence and Spread in Water Bodies. *Frontiers in Microbiology*, *3*. https://doi.org/10.3389/fmicb.2012.00018

MacDougall, C., & Polk, R. E. (2005). Antimicrobial Stewardship Programs in Health Care Systems. *Clinical Microbiology Reviews*, *18*(4), 638–656. https://doi.org/10.1128/cmr.18.4.638-656.2005

Maragakis, L. L., Perencevich, E. N., & Cosgrove, S. E. (2008). Clinical and economic burden of antimicrobial resistance. *Expert Review of Anti-infective Therapy*, *6*(5), 751–763. https://doi.org/10.1586/14787210.6.5.751

Mattar, C., Edwards, S., Baraldi, E., & Hood, J. (2020). An overview of the global antimicrobial resistance research and development hub and the current landscape. *Current Opinion in Microbiology*, *57*, 56–61. https://doi.org/10.1016/j.mib.2020.06.009

McKernan, C., Benson, T., Farrell, S., & Dean, M. (2021). Antimicrobial use in agriculture: critical review of the factors influencing behaviour. *JAC-Antimicrobial Resistance*, *3*(4). https://doi.org/10.1093/jacamr/dlab178

Memish, Z. A., Venkatesh, S., & Shibl, A. M. (2003). Impact of travel on international spread of antimicrobial resistance. *International Journal of Antimicrobial Agents*, *21*(2), 135–142. https://doi.org/10.1016/s0924-8579(02)00363-1

Mittal, A. K., Bhardwaj, R., Mishra, P., & Rajput, S. K. (2020). Antimicrobials Misuse/Overuse: Adverse Effect, Mechanism, Challenges and Strategies to Combat Resistance. *The Open Biotechnology Journal*, *14*(1), 107–112. https://doi.org/10.2174/1874070702014010107

Mlynarczyk-Bonikowska, B., Kowalewski, C., Krolak-Ulinska, A., & Marusza, W. (2022). Molecular Mechanisms of Drug Resistance in Staphylococcus aureus. *International Journal of Molecular Sciences*, *23*(15), 8088. https://doi.org/10.3390/ijms23158088

Otto, M. (2013). Community-associated MRSA: What makes them special? *International Journal of Medical Microbiology*, *303*(6–7), 324–330. https://doi.org/10.1016/j.ijmm.2013.02.007

Paulson, J. A., Zaoutis, T. E., Paulson, J. A., Ahdoot, S., Baum, C. R., Bole, A., Brumberg, H. L., Campbell, C. C., Lanphear, B. P., Lowry, J. A., Pacheco, S. E., Spanier, A. J., Trasande, L., Byington, C. L., Maldonado, Y. A., Barnett, E. D., Davies, H. D., Edwards, K. M., Jackson, M. A., & Zaoutis, T. E. (2015). Nontherapeutic Use of Antimicrobial Agents in Animal Agriculture: Implications for Pediatrics. *Pediatrics*, *136*(6), e1670–e1677. https://doi.org/10.1542/peds.2015-3630

Pokharel, S., Raut, S., & Adhikari, B. (2019). Tackling antimicrobial resistance in low-income and middle-income countries. *BMJ Global Health*, *4*(6), e002104. https://doi.org/10.1136/bmjgh-2019-002104

Rehman, S. (2023). A parallel and silent emerging pandemic: Antimicrobial resistance (AMR) amid COVID-19 pandemic. *Journal of Infection and Public Health*, *16*(4), 611–617. https://doi.org/10.1016/j.jiph.2023.02.021

Roberts, M., Burgess, S., Toombs-Ruane, L., Benschop, J., Marshall, J., & French, N. (2021). Combining mutation and horizontal gene transfer in a within-host model of antibiotic resistance. *Mathematical Biosciences*, *339*, 108656. https://doi.org/10.1016/j.mbs.2021.108656

Shamas, N., Stokle, E., Ashiru-Oredope, D., & Wesangula, E. (2023). Challenges of implementing antimicrobial stewardship tools in Low to Middle Income Countries (LMICs). *Infection Prevention in Practice*, *5*(4), 100315. https://doi.org/10.1016/j.infpip.2023.100315

Siegel, J. D., Rhinehart, E., Jackson, M., & Chiarello, L. (2007). 2007 Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Health Care Settings. *American Journal of Infection Control*, *35*(10), S65–S164. https://doi.org/10.1016/j.ajic.2007.10.007

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

Sirijatuphat, R., Sripanidkulchai, K., Boonyasiri, A., Rattanaumpawan, P., Supapueng, O., Kiratisin, P., & Thamlikitkul, V. (2018). Implementation of global antimicrobial resistance surveillance system (GLASS) in patients with bacteremia. *PLoS ONE*, *13*(1), e0190132. https://doi.org/10.1371/journal.pone.0190132

Sulis, G., Sayood, S., & Gandra, S. (2021). Antimicrobial resistance in low- and middle-income countries: current status and future directions. *Expert Review of Anti-infective Therapy*, *20*(2), 147–160. https://doi.org/10.1080/14787210.2021.1951705

Tacconelli, E., & Cataldo, M. A. (2008). Vancomycin-resistant enterococci (VRE): transmission and control. *International Journal of Antimicrobial Agents*, *31*(2), 99–106. https://doi.org/10.1016/j.ijantimicag.2007.08.026

Tang, K. W. K., Millar, B. C., & Moore, J. E. (2023). Antimicrobial Resistance (AMR). *British Journal of Biomedical Science*, *80*. https://doi.org/10.3389/bjbs.2023.11387

Weinstein, R. A. (2001). Controlling Antimicrobial Resistance in Hospitals: Infection Control and Use of Antibiotics. *Emerging Infectious Diseases*, *7*(2), 188–192. https://doi.org/10.3201/eid0702.010206