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How Does Antibiotic Misuse Contribute to Rise of Antimicrobial Resistance

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How Does Antibiotic Misuse Contribute to Rise of Antimicrobial Resistance

The discovery and mass production of antibiotics was a paradigm shift in the field of medicine, turning once- disastrous diseases into a condition that could be treated successfully. These antibiotic drugs not only became the foundation of healthcare in the modern era, but the achievement of complex medical procedures, such as organ transplants, chemotherapy, and major surgery, all of which are based on the capability of prevention and control of bacterial infections, became possible. Nevertheless, this utopian vision of medicine is seriously jeopardized. It is the same strong force of evolution that created life on the earth and is now making these life-saving drugs useless. Antimicrobial resistance (AMR) has become one of the most urgent global public health issues of the 21st century. Although AMR is a multi-factorial, multi-dimensional phenomenon with different causes in the human, animal, and environmental domains, the main cause is the use and excessive use of antibiotics. In this paper, it will be argued that the overuse or incorrect use of antibiotics function as a potent selective pressure causing the evolution and spread of resistant bacteria, the very basis of modern medicine, and thus requiring immediate, global action.

Evolutionary Basis of Antimicrobial Resistance

To comprehend the role played by misuse in breeding resistance, one has to first of all value the underlying biological phenomenon, which is natural selection. The use of antibiotics does not have an evolutionary history of being a modern invention. Most of them are based on the natural substances naturally synthesized by soil fungi and bacteria to attract resources. As a result, bacteria have developed highly resistant mechanisms in millions of years (Irfan et al., 2022). These processes are enzymatic degradation (e.g., beta-lactamases that degrade penicillin), localization of the drug (e.g., mutation of ribosomal RNA, which prevents the binding of the antibiotic), decreased cell membrane permeability, and active efflux pumps that expel the antibiotic through the cell.

Antibiotics are a powerful selection force when they are introduced into an environment that has a diverse population of bacteria. Vulnerable bacteria are killed, and any bacteria that happen to have a pre-existing resistance gene (through mutation or horizontal gene transfer) survive and grow without any competition. This is a purely natural process. The issue is that, when human activity results in the development of massive and continuous selective pressure, this evolutionary process can significantly increase its velocity. Each case of unneeded or inappropriate antibiotic usage gives a chance for resistance to develop, multiply, and be transmitted (Barman et al., 2024). A course of antibiotics, as the very pretext of minimizing this risk, is meant to defeat the infection before resistant sub-populations develop. Misuse is a subversion of this strategy and transforms a potent tool of therapy into an evolution of a high-stakes experiment.

Misuse at the Heart of Human Healthcare

The main cause of antibiotic misuse is in the field of human health care, and it takes various critical forms. First of all, there is improper prescriptive practice. It is astounding that a large percentage of antibiotics given to people are unnecessary or unnecessarily prescribed. This is especially egregious with acute respiratory tract infections (ARTIs), including the common cold, bronchitis, and sore throats, of which the vast majority are viral in etiology. Antibiotics have no effect whatsoever against viruses, but research results continue to indicate that physicians are prescribing antibiotics at alarmingly high rates in regard to ARTIs (Zulfkar et al., 2025). The combination of causes of this practice is complicated: the uncertainty of diagnosis (inability to differentiate between viral and bacterial infections), time pressure in the consultation, patient expectation (I need an antibiotic to get better), and a defensive medicine practice (better safe than sorry). Every one of these prescriptions offers an unwarranted selective pressure to the commensal flora (those harmless bacteria) of the patient and selects resistant strains to lead to opportunistic infections (UTI, surgical site infections, or bloodstream infections) that become hard to treat.

Second, there is a mismanagement of the idea behind the broad-spectrum vs. narrow-spectrum antibiotics. Widespread use of broad-spectrum antibiotics (which cause a large number of bacteria to die) is often prescribed when the narrow-spectrum agent (which attacks the exact causative pathogen) would be sufficient (Walsh et al., 2023). This method of carpet-bombing has a larger selective pressure, where a larger fraction of the protective microbiome of the patient is eliminated, and this leaves a stronger opportunity of growth to resistant organisms, including Clostridioides difficile (George et al., 2022). Of particular concern is the fact that overuse of the last-resort antibiotics, such as carbapenems and colistin, is used to treat infections that can be treated by first-line agents, which is directly threatening the performance of our last line of defense.

Third, non-adherence by patients is a contributing factor to the problem. Failure of the patient to take the entire course even when the antibiotic is rightfully prescribed can be a fatal cause, especially when the patient tends to quit as he begins to feel better. This sub-lethal exposure will leave behind the most resistant and partly resistant bacteria to survive and maybe multiply so that the infection will return in a more resistant form (Nazir et al., 2025). Although the old adage of always completing the course is currently undergoing a refinement by infected disease professionals (who note that the course duration itself is often inappropriately prolonged), the same rule stands that truncated or inconsistent dosing provides an ideal environment in which resistance can arise.

Fourth, in most regions of the world, antibiotics are sold over the counter. This easy accessibility through over-the-counter (OTC) and absence of regulation and diagnostic facilities promotes self-medication. Patients can take the inappropriate antibiotic or an incorrect dosage, or they can take them in the case of improper indications (e.g., a low-grade fever of viral origin) (Tang et al., 2023). This unchecked usage is a huge and uncontrolled source of selective pressure that is highly hard to track or regulate.

The Use of Antibiotics in Food Production.

Although abuse in human medicine is also a critical factor, the application of antibiotics in animal agriculture, especially livestock production, is a parallel and equally important cause of the global AMR crisis. The percentage of all antibiotic sales that have been used in food animals has been very high—in some countries as much as 70-80 percent of the total sales.

The historical growth-promotion behavior of antibiotics was founded on the finding that sub-therapeutic doses given to healthy animals resulted in greater weight gain and higher feed efficiency. Although this practice is economically friendly, it is a classic technique of making people resistant (Singh et al., 2024). Repeatedly subjecting animals to low levels of antibiotics provides the perfect setting in which bacterial strains that turn out to be resistant can be selected and multiplied. The resistant bacteria might survive in the microbiomes of the guts of animals and subsequently transmit via a variety of means: direct animal-to-animal contact, farm environment (soil, water) contamination, and not least, the food chain.

The risks to human health are manifold. First, foodborne pathogens such as Salmonella and Campylobacter may develop resistance on the farm, resulting in people being infected with them and not responding to the normal treatment. Second, and perhaps more perniciously, commensal bacteria such as Escherichia coli and Enterococci may become huge reservoirs of mobile resistance genes. These are plasmid- or other mobile-based genes that may be transferred to human pathogens in the human gut following the consumption of contaminated food or exposure to the environment (Patra et al., 2025). The appearance of colistin resistance through the mcr-1 gene that started in livestock in China and the global dissemination of the gene give a strong warning. Colistin was a final resort for human infections, and its wide use in agriculture made it less effective in human medicine.

The connection between agricultural use of antibiotics and human AMR is now beyond any doubt, and there are international demands that the use of medically important antibiotics as growth promoters and as routine disease preventers should be stopped. The trend of more responsible use, called "antimicrobial stewardship," is gradually finding some ground in the agricultural sector but is still disproportionate across the globe.

Environmental Pathways

The environment serves as a huge storage and a means of spread for antibiotic-resistant bacteria and resistance genes. Inappropriate antibiotic use in human medicine and agriculture causes the entering of antibiotics into the environmental compartments and generates a continuous selective pressure that is not placed in clinical and farm environments.

Most of the antibiotics are released into the urine and feces in significant quantities and enter the wastewater treatment plants (WWTPs). A lot of WWTPs are not developed to eliminate these complicated pharmaceutical substances to the full. This guarantees that effluents released in rivers and streams have lower traces of antibiotics. These sub-inhibitory concentrations are especially problematic because they are able to promote horizontal gene transfer and are also able to select resistance even at levels very low compared to the minimum inhibitory concentration that defines clinical resistance (Nammi et al., 2025). Moreover, the biosolids (sludge) generated by WWTPs are commonly displaced onto agricultural land as fertilizer, which places both the leftover antibiotics and the antibiotic-resistant bacteria directly into the microbiome of the soil.

Consequences: A Post-Antibiotic Era

The effects of untamed AMR are far-reaching and go way beyond the treatment of simple infections. The next generation of people is experiencing the threat of a post-antibiotic era, where simple infections and minor injuries can be fatal again.

AMR causes mortality and morbidity in clinical practice. The treatment failure, long hospitalizations, and use of more toxic and expensive and generally less effective second- and third-line drugs are experienced more frequently by patients with resistant infections (Aljeldah, 2022). E.g., the emergence of methicillin-resistant Staphylococcus aureus (MRSA) and carbapenem-resistant Enterobacteriaceae (CRE), also termed "nightmare bacteria," has turned the mundane hospital-acquired infections into life-threatening emergencies with higher than 50% mortality rates in certain cases.

It is not just infectious disease threatening us. The capability to treat and prevent bacterial infections is the cornerstone of the safety of contemporary medicine. Even surgical operations that are elective, such as hip replacement and cesarean section, have an underlying risk of infection. Febrile neutropenia can only be treated using effective antibiotics since chemotherapy that suppresses the immune system is only possible. There are long-term prophylaxis antibiotic requirements for organ and stem cell transplant recipients to avoid causing fatal infections. The absence of good antibiotics would make these pillars of modern medicine high-risk, usually impossible, interventions (Salam et al., 2023). Reality: The depletion of our stocks of antibiotics has the effect of effectively unraveling a century of medical advancement.

Response to the Crisis

The development of AMR response is a complex process that needs to be fought as a coordinated effort that promotes the understanding of the interrelation between human, animal, and environmental health as one health. The cornerstone in this initiative is antimicrobial stewardship—a series of joint measures that can enhance the antimicrobials' use through maximization of antimicrobial choice, dosage, duration, and route of administration (Endale et al., 2023). In the human medical field, this implies the introduction of diagnostic stewardship (rapid tests to determine bacterial infections before prescribing), the creation of evidence-based prescribing methods, and the educational actions of clinicians and civilians to change the perception of unnecessary usage of antibiotics.

The application of stewardship in the agricultural sector would entail no longer using medically important antibiotics as growth promoters and ensuring strict regulations over their use as disease prevention and treatment methods so that they could only be utilized under veterinary guidance (Bo et al., 2024). This should be accompanied by investment in animal husbandry practices, including better hygiene, vaccination, and biosecurity, in order to lessen the requirement of antibiotics in the first instance.

More importantly, such initiatives should be based on international cooperation. The AMR is borderless; the resistant bacteria and genes are moving across continents freely with the human travel and trade, as well as migration. Thus, global initiatives, including the Global Action Plan on AMR under the authority of the World Health Organization (WHO) with the help of the Food and Agriculture Organization (FAO) and the World Organization of Animal Health (OIE), are necessary (Adebisi, 2023). These frameworks require action plans at the national level, enhanced surveillance systems, prevention and control of infection, and investment in the research and development of new antibiotics, diagnostics, and vaccines. The antibiotic development business model is flawed; the antibiotic pipeline has been stagnant for decades and needs a push-pull incentive system that includes public-private partnerships to jumpstart the system.

Conclusion

Antimicrobial resistance is not a natural occurrence that is impossible to control. To a huge extent, it is a self-inflicted crisis that has been brought about by decades of antibiotic abuse and overuse in the fields of human medicine, agriculture, and the environment. Unconsciously, we have developed a high-stakes, worldwide evolution game, and our natural selection is picking up speed to such an extent that our strongest drugs are already being rendered useless. Such repercussions of not taking action are less than a civic health disaster: a future where even basic surgery is life-threatening, treatable illnesses are no longer possible, and the current medical system as we understand it will be unable to continue. It is a silent pandemic that must be solved by making a radical change in our perception and utilization of these valuable resources. It requires a shift toward a convenience and excess culture from a stewardship and responsibility culture. It demands that clinicians be accurate when prescribing, patients be accurate when taking antibiotics, farmers be sustainable in their practices, and policymakers establish effective regulatory frameworks that do not focus on economic benefits in the short term at the expense of long-term population health. We are running out of time to maintain the effectiveness of our existing antibiotics and develop new antibiotics. An organized, international, and undeterred effort to fight the abuse of antibiotics is not only a health policy measure; it is a very fundamental investment in the safeguarding of the future of medicine itself.

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