

**ANTIMICROBIAL RESISTANCE: A GROWING GLOBAL
HEALTH CHALLENGE**

Husanova Sevinch Otabek qizi

3rd-year student, Faculty of General Medicine

Kimyo International University in Tashkent, Uzbekistan

Abstract. Antimicrobial resistance (AMR) occurs when bacteria, viruses, fungi and parasites no longer respond to the medicines designed to kill them, making common infections harder or impossible to treat. This review summarises the current evidence on the global burden of bacterial AMR, its main drivers, the pathogens of greatest concern and the strategies proposed to contain it. According to the Global Research on Antimicrobial Resistance (GRAM) project, bacterial AMR was directly responsible for 1.27 million deaths and associated with 4.95 million deaths in 2019; forecasts to 2050 predict 1.91 million attributable and 8.22 million associated deaths per year, with 39 million cumulative attributable deaths between 2025 and 2050. The 2025 WHO surveillance report shows that one in six laboratory-confirmed bacterial infections worldwide was resistant to antibiotics in 2023. The article discusses the role of antibiotic overuse in human medicine and agriculture, weak infection prevention, limited diagnostics and the slow development of new antibiotics, and outlines the One Health approach, antimicrobial stewardship, vaccination and surveillance as the main pillars of the global response. Implications for medical education and for Uzbekistan are considered.

Keywords: antimicrobial resistance, antibiotics, global burden, ESKAPE pathogens, MRSA, antimicrobial stewardship, One Health, surveillance.

INTRODUCTION

The discovery of penicillin by Alexander Fleming in 1928 and its introduction into clinical practice in the 1940s transformed medicine. Infections that had been a leading cause of death became curable, and modern surgery, cancer chemotherapy, organ transplantation and intensive care became possible because antibiotics could prevent and treat the infections associated with them. Yet in his Nobel lecture of 1945 Fleming himself warned that the misuse of penicillin could lead to the selection of resistant bacteria [1].

Eight decades later, this warning has become reality. Antimicrobial resistance (AMR) arises when microorganisms evolve mechanisms that protect them from the effects of antimicrobial drugs. Resistance is a natural evolutionary process, but it is greatly accelerated by the excessive and inappropriate use of antimicrobials in humans, animals and agriculture. The World Health Organization (WHO) lists AMR among the top global public health threats facing humanity, and the United Nations General Assembly adopted a political declaration on AMR in 2024 [2].

The aim of this article is to review the current evidence on the scale of the AMR problem, its causes and the most dangerous resistant pathogens, and to outline the strategies needed to address it, with particular attention to the role of future physicians.

MATERIALS AND METHODS

This article is a narrative review. Data were drawn from the systematic analyses of the GRAM project published in The Lancet in 2022 and 2024 [3,

4], from the WHO Global Antibiotic Resistance Surveillance Report 2025 and the WHO Bacterial Priority Pathogens List 2024 [2, 5], and from key international reports and reviews on AMR policy [6, 7]. Quantitative estimates are presented in figures and tables; the original uncertainty intervals are reported where available.

RESULTS

3.1. The global burden of AMR. The most comprehensive estimate of the burden of bacterial AMR was produced by the GRAM project. In 2019, an estimated 4.95 million deaths (95% uncertainty interval [UI] 3.62–6.57 million) were associated with bacterial AMR, of which 1.27 million (95% UI 0.911–1.71 million) were directly attributable to resistance [3]. This means that AMR caused more deaths than HIV/AIDS or malaria in the same year. The burden was highest in western sub-Saharan Africa, with 27.3 deaths per 100,000 population, and lowest in Australasia, with 6.5 deaths per 100,000 [3].

The follow-up analysis covering 1990–2021 and forecasting to 2050 showed that more than one million people died each year as a direct result of AMR throughout this period. In 2021, 1.14 million deaths were attributable to and 4.71 million were associated with bacterial AMR. If current trends continue, attributable deaths are forecast to rise to 1.91 million and associated deaths to 8.22 million in 2050, and a cumulative 39 million people are expected to die directly from AMR between 2025 and 2050 [4]. These figures are shown in Figure 1.

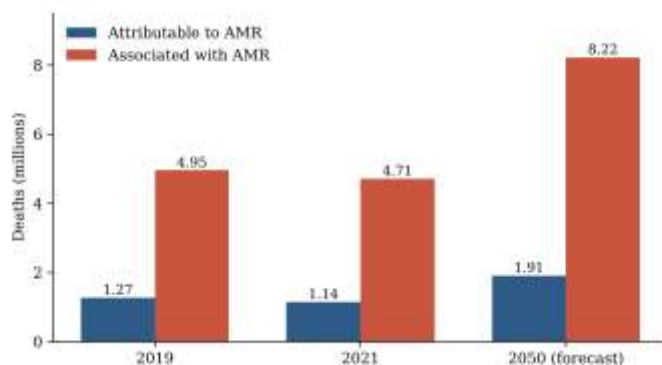


Figure 1. Global deaths attributable to and associated with bacterial AMR, 2019, 2021 and forecast for 2050 (data: GRAM project [3, 4])

The age distribution of the burden is changing. Between 1990 and 2021, AMR deaths among children under five fell from 488,000 to 193,000, largely because of vaccination and improved water, sanitation and hygiene, whereas deaths among adults aged 70 years and older increased by more than 80% [4]. As populations age, the burden of AMR is therefore shifting towards older adults, who are more often hospitalised and exposed to invasive procedures.

3.2. Current resistance levels. The WHO Global Antibiotic Resistance Surveillance Report 2025, based on data reported by more than 100 countries, found that one in six laboratory-confirmed bacterial infections worldwide in 2023 was caused by bacteria resistant to antibiotic treatment. Between 2018 and 2023, resistance increased in more than 40% of the pathogen–antibiotic combinations monitored, with an average annual rise of 5–15%. Resistance was highest in the WHO South-East Asia and Eastern Mediterranean regions, where one in three infections was resistant, and in the African region, where one in five was resistant [2]. More than 40% of *Escherichia coli* and over 55% of *Klebsiella pneumoniae* isolates worldwide were resistant to third-generation cephalosporins, the first-line treatment for many serious infections [2]. Regional differences are illustrated in Figure 2.

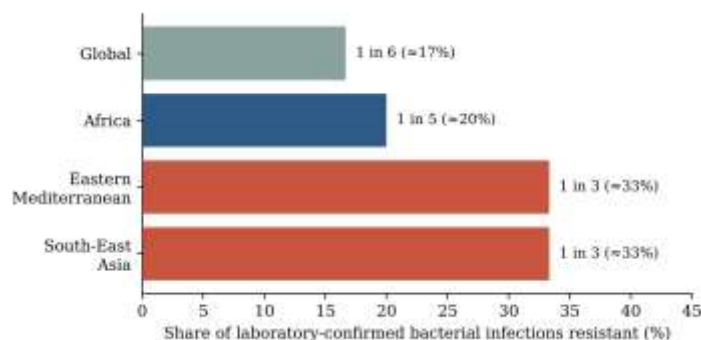


Figure 2. Share of laboratory-confirmed bacterial infections resistant to antibiotics in 2023, by WHO region (data: WHO GLASS 2025 [2])

3.3. Pathogens of greatest concern. Six pathogens – *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Streptococcus pneumoniae*, *Acinetobacter baumannii* and *Pseudomonas aeruginosa* – were responsible for 929,000 deaths attributable to AMR and 3.57 million deaths associated with AMR in 2019 [3]. Methicillin-resistant *S. aureus* (MRSA) alone caused more than 100,000 attributable deaths, and MRSA deaths more than doubled between 1990 and 2021, the largest increase of any pathogen–drug combination studied [3, 4]. The WHO Bacterial Priority Pathogens List 2024 classifies resistant pathogens into critical, high and medium priority groups to guide research and development (Table 1) [5].

Table 1. Selected pathogens from the WHO Bacterial Priority Pathogens List 2024 [5]

Priority group	Pathogen and resistance	Typical infections
Critical	<i>Acinetobacter baumannii</i> , carbapenem-resistant	Ventilator-associated pneumonia, bloodstream infections

Priority group	Pathogen and resistance	Typical infections
Critical	Enterobacterales, third-generation cephalosporin-resistant	Urinary tract and bloodstream infections
Critical	Enterobacterales, carbapenem-resistant	Hospital-acquired infections, sepsis
Critical	Mycobacterium tuberculosis, rifampicin-resistant	Multidrug-resistant tuberculosis
High	Pseudomonas aeruginosa, carbapenem-resistant	Hospital-acquired pneumonia, wound infections
High	Staphylococcus aureus, methicillin-resistant	Skin, soft-tissue and bloodstream infections
High	Neisseria gonorrhoeae, cephalosporin/fluoroquinolone-resistant	Gonorrhoea
Medium	Streptococcus pneumoniae, macrolide-resistant	Pneumonia, otitis media, meningitis

3.4. Drivers of resistance. Resistance develops through genetic mutations and through the horizontal transfer of resistance genes between bacteria, for example on plasmids. Antibiotic use exerts selective pressure that allows resistant strains to survive and spread. The main drivers identified in the literature are summarised in Table 2. They include the overuse and misuse of antibiotics in human medicine, such as prescribing antibiotics for viral infections, the sale of antibiotics without prescription, incomplete courses of

treatment, the extensive use of antimicrobials in livestock for growth promotion and disease prevention, poor infection prevention and control in health facilities, inadequate water and sanitation, limited access to diagnostics, and international travel and trade [6, 7].

Table 2. Main drivers of antimicrobial resistance and corresponding interventions

Domain	Driver	Intervention
Human medicine	Unnecessary prescribing, e.g. for viral infections	Antimicrobial stewardship, prescribing guidelines
Community	Self-medication and over-the-counter sale	Prescription-only regulation, public awareness
Health facilities	Poor infection prevention and control	Hand hygiene, screening, isolation
Diagnostics	Empirical treatment without microbiological testing	Rapid diagnostic tests, laboratory capacity
Agriculture	Antibiotics for growth promotion in livestock	Ban on growth promoters, veterinary oversight
Environment	Antibiotic residues in wastewater	Wastewater treatment, pollution control
Innovation	Weak pipeline of new antibiotics	Pull incentives, public–private partnerships

4. DISCUSSION

The data reviewed above show that AMR is not a distant threat but a present and growing cause of death and disability. The forecasts of the GRAM project indicate that without effective action the number of deaths directly attributable to AMR will increase by about two-thirds by 2050 [4]. In 2016 the Review on Antimicrobial Resistance chaired by Jim O’Neill estimated that AMR could cause 10 million deaths a year by 2050 and cost the global economy up to 100 trillion US dollars in lost output [6]. Although the methods of these estimates differ, they agree that the human and economic costs of inaction would be enormous.

Because resistant bacteria and resistance genes move freely between humans, animals and the environment, AMR can only be addressed through a One Health approach that coordinates action across human medicine, veterinary medicine, agriculture and environmental protection. The WHO Global Action Plan on AMR, adopted in 2015, sets out five objectives: improving awareness and understanding of AMR; strengthening surveillance and research; reducing the incidence of infection; optimising the use of antimicrobials; and ensuring sustainable investment in new medicines, diagnostics and vaccines [7].

Several interventions have particular potential. Antimicrobial stewardship programmes in hospitals, which promote the selection of the right drug, dose and duration, reduce unnecessary antibiotic use without compromising patient outcomes. Vaccination prevents infections and therefore the need for antibiotics; the decline of AMR deaths among young children since 1990 illustrates this effect [4]. Better access to diagnostics allows physicians to distinguish bacterial from viral infections and to choose targeted therapy. The GRAM analysis estimated that improving the care of severe infections and access to antibiotics could save up to 92 million lives

between 2025 and 2050, and that the development of new antibiotics against Gram-negative bacteria could avert up to 11 million deaths [4].

These findings are directly relevant to medical students and young physicians. Future doctors will be the main prescribers of antibiotics, and their knowledge and attitudes will determine whether antibiotics remain effective. Medical curricula should therefore include training in the principles of rational antibiotic use, the interpretation of microbiological results and infection prevention. In Uzbekistan, as in other countries of Central Asia, strengthening laboratory surveillance, enforcing prescription-only access to antibiotics and implementing hospital stewardship programmes are important steps towards controlling AMR.

CONCLUSION

Antimicrobial resistance is one of the most serious global health challenges of the twenty-first century. Bacterial AMR was directly responsible for more than one million deaths a year between 1990 and 2021, and this number is forecast to approach two million by 2050. One in six bacterial infections worldwide is already resistant to treatment, with much higher levels in South-East Asia, the Eastern Mediterranean and Africa. The main drivers are the overuse and misuse of antibiotics, poor infection prevention, limited diagnostics and an insufficient pipeline of new drugs. Containing AMR requires coordinated One Health action, including stewardship, vaccination, surveillance, improved diagnostics and investment in research. Physicians, and future physicians, have a central role to play in preserving the effectiveness of antibiotics for future generations.

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