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Review Article

Irrational Use of Antibiotics: A Global Threat to Public Health

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Improper, excess, or unwarranted use of antimicrobial agents in the prevention and treatment of infectious diseases is called irrational use of antibiotics. This encompasses administering the antibiotics without effective clinical or microbiological diagnosis, treating viral infections with antibiotics, improper choice of broad-spectrum agents, inappropriate dosage, excessive treatment period, and self-treatment, which cannot be successful without the supervision of a professional. The irrational practices have become a leading universal health issue in the world because the practice contributes directly to the rapid emergence and propagation of antimicrobial resistance (AMR).Antimicrobial resistance is a significant cause of failure of treatment outcome, a lengthy duration of illness, longer hospital stays, and higher healthcare expenses coupled with high morbidity and mortality as well as the reduction of effectiveness of popular antibiotics.The current review will have a broad view of the irrational use of antibiotics, their historical development, classification, and actions, as well as the disease-specific first-line antibiotic therapy. The pharmacological and clinical outcomes of irrational antibiotic use are also mentioned in the review with the help of recorded case studies such as organ toxicity, secondary infection, and life-threatening adverse drug reactions. Besides, rational prescribing practices, therapeutic drug monitoring, antimicrobial stewardship initiatives, and patient education are highlighted as key measures that need to be adopted in the fight against AMR.The rational use of antibiotics should be encouraged in order to protect the clinical usefulness of these drugs, patient safety, and the health of the population. Regulatory frameworks should be tightened; more attention should be paid to the population in order to reduce the danger of increasing the risk of antimicrobial resistance.

Keywords: Irrational use, antibiotics, self-medication, rational drug use, public health.

INTRODUCTION

Antibiotics are one of the greatest developments in contemporary medicine, and they have been of great importance in minimizing morbidity and mortality that come with bacterial infections. Antibiotics, ever since their discovery, have revolutionized the treatment of infectious diseases previously thought to be fatal, like pneumonia, tuberculosis, septicemia, and postoperative wound infections. Having high accessibility and great efficacy, they have brought many changes to the life expectancy and general population health. Nevertheless, regardless of these advantages, irrational use of antibiotics has become a threat to the global health challenge, and it is expected to erode decades of medical achievement. Irrational use of antibiotics happens when they are administered, used, and taken without proper medical explanations, with the wrong drug choice, with the wrong dosing, with an insufficient treatment course, and with improper monitoring. The typical ones are treating viral diseases like the common cold and influenza with antibiotics when there is no need, prescribing broad-spectrum antibiotics when the infection does not warrant such treatment, self-prescription, not completing a full course of medications, and non-conformance with usual guidelines of therapy. These are common in developed and developing nations but commonly found in the low- and middle-income areas with easy access to antibiotics and weak regulations. Among the most severe outcomes of the unreasonable use of antibiotics, the emergence of antimicrobial resistance is mentioned. Antimicrobial resistance occurs when bacteria become adapted in order to survive in the presence of antibiotics, which makes normal treatment unproductive. The resistant infections have been linked to longer disease duration, risky development of complications, longer hospitalization, and increased death. In addition, treating the resistant infections is frequently associated with costly, harmful, or last-resort antibiotic drugs, which creates a heavy economic burden on the health care system and patients. Besides being resistant, irrational use of antibiotics can be a cause of adverse drug reactions, organ toxicity, secondary infections, and alteration of normal microbial flora. Low populations like infants and the elderly, pregnant women, and patients who are in critical conditions are some of the people who face a great danger of experiencing dire effects due to inappropriate antibiotic treatment. These risks are also worsened by the absence of regular monitoring, surveillance of therapy drugs, and follow-up of patients. A number of reasons attach to the irrational use of antibiotics, with the following including the lack of adequate diagnosis facilities, the insufficiency of knowledge by the patient and healthcare providers themselves, patient expectations to be covered, influences of pharmaceutical companies' marketing, and inadequate adoption of antimicrobial stewardship programs. In most circumstances, antibiotics are seen as an easy way out of infections, hence their unsuitable usage even when they do not afford clinical advantage. This review will help us to answer the question regarding the irrationality of antibiotic use by discussing their history, classification, mechanism of action, and the first-line therapy of different diseases. It also explores clinical and pharmacological implications of irrational use of antibiotic by using real-life cases. The review reveals the key approaches to overcome the antimicrobial resistance and guarantee the safe and effective use of antibiotics in clinical practice by underlining the significance of rational prescribing, antimicrobial stewardship, patient education, and enforcing regulations.

Classification:

Mechanism of Action of Antibiotics:

Antibiotics act by targeting specific structural or functional components of bacterial cells. Understanding their mechanisms of action is essential for rational antibiotic use, as misuse accelerates the development of antimicrobial resistance.

1. Inhibition of Cell Wall Synthesis

Principle: Bacteria possess a rigid cell wall made of peptidoglycan, which maintains cell shape and prevents osmotic rupture.

Human cells lack a cell wall → selective toxicity.

Mechanism of Action (MOA): Antibiotics inhibit enzymes involved in peptidoglycan synthesis (Penicillin-Binding Proteins, PBPs).

How It Works:

- Antibiotic binds to PBPs
- Cross-linking of peptidoglycan chains is inhibited
- Cell wall becomes weak
- Osmotic pressure causes cell lysis and death

Examples: Penicillins (Penicillin G, Amoxicillin), Cephalosporins, Carbapenems, Vancomycin

2. Inhibition of Protein Synthesis

Principle: Bacterial ribosomes are 70S (30S + 50S) and differ from human ribosomes (80S). Antibiotics selectively target bacterial ribosomes.

Mechanism of Action (MOA): Antibiotics bind to either the 30S or 50S ribosomal subunit, preventing protein synthesis.

How It Works:

- Binding blocks initiation or elongation of peptide chains
- Faulty or incomplete proteins are formed
- Essential enzymes are not produced
- Bacterial growth stops or cell dies

Examples: 30S inhibitors: Aminoglycosides, Tetracyclines

50S inhibitors: Macrolides, Chloramphenicol, Clindamycin

3. Inhibition of Nucleic Acid Synthesis

Principle: DNA replication and RNA transcription are essential for bacterial multiplication.

Mechanism of Action (MOA): Antibiotics inhibit enzymes involved in DNA or RNA synthesis.

How It Works:

- Inhibition of DNA gyrase → DNA cannot unwind
- Inhibition of RNA polymerase → mRNA not formed
- Protein synthesis stops
- Bacterial cell dies

Examples: Fluoroquinolones (Ciprofloxacin, Levofloxacin), Rifampicin, Metronidazole

4. Inhibition of Metabolic Pathways (Antimetabolites)

Principle: Bacteria synthesize folic acid for DNA production. Humans obtain folic acid from diet.

Mechanism of Action (MOA): Antibiotics block enzymes involved in folic acid synthesis.

How It Works:

- Sulfonamides inhibit dihydropteroate synthase
- Trimethoprim inhibits dihydrofolate reductase
- Folic acid synthesis stops
- DNA synthesis fails → growth inhibition

Examples: Sulfonamides, Trimethoprim, Co-trimoxazole

Disease	First-line Antibiotic
Streptococcal pharyngitis	Penicillin V / Amoxicillin
Acute otitis media	Amoxicillin
Acute bacterial sinusitis	Amoxicillin-clavulanate
Community-acquired pneumonia	Amoxicillin / Azithromycin
Hospital-acquired pneumonia	Piperacillin–Tazobactam
Tuberculosis	Isoniazid + Rifampicin + Pyrazinamide + Ethambutol
Uncomplicated UTI	Nitrofurantoin
Complicated UTI	Ceftriaxone
Pyelonephritis	Ciprofloxacin
Typhoid fever	Ceftriaxone / Azithromycin
Cholera	Doxycycline
Bacterial dysentery	Ciprofloxacin
H. pylori infection	Amoxicillin + Clarithromycin + PPI
Impetigo	Mupirocin (topical)
Cellulitis	Cephalexin
Skin abscess	Clindamycin
MRSA infection	Linezolid / Vancomycin
Gonorrhea	Ceftriaxone
Chlamydia	Azithromycin / Doxycycline

History of Antibiotics:

Antibiotics history can be regarded as one of the most significant milestones in the sphere of medicine. Pneumonia, tuberculosis, wound infections, and septicemia are some of the bacterial infections that before the advent of antibiotics were usually fatal. Infections were also very dangerous to the life of the minor injuries and surgical procedures. This was the onset of the antibiotic era which began in 1928 when Alexander Fleming accidentally discovered penicillin that was produced by the fungus Penicillium notatum. Fleming noted that the growth of Staphylococcus bacteria was retarded near the mold. Isolation and mass production however were not immediately available and penicillin was not used in clinical practice. The purification of penicillin and the development of large-scale production of penicillin was achieved in the 1940s by scientists Howard Florey and Ernst Boris Chain. Penicillin was common in world war II, which led to the death of a number of soldiers due to wound infection being reduced greatly. This was a breakthrough in the cure of bacterial diseases and is commonly known as the "Golden Age of Antibiotics." Subsequently after penicillin, there was a line of subsequent antibiotics that were identified between the years 1940 and 1960, which included streptomycin, tetracyclines, chloramphenicol, and erythromycin. These medications increased the range of bacterial infections that could be cured successfully. But the emergence of antibiotic resistance started soon after the mass use of the antibiotics. Misprescription, overuse, self-treatment, and the lack of medical treatment have led to the emergence of the resistant strains of bacteria. Towards the end of the 20th century, the issue of resistance to widely used antibiotics had become a significant issue worldwide. Over the last few decades, new antibiotics have been developed at a slower pace, as the resistance has been increasing. This has changed the emphasis of the world to logical application of antibiotics, antimicrobial stewardship schemes and stringent regulations to maintain efficacy of available antibiotics.

Case Studies on Irrational Use of Antibiotics:

Case 1 — Gray Baby Syndrome due to Chloramphenicol Overdose in a Neonate

- **Patient:** 1-month-old female infant, 2.5 kg, under-developed and hospitalized for presumed bacterial sepsis.
- **Irrational Use:** Chloramphenicol administered at 150 mg/day (~60 mg/kg/day) for three days — an excessive neonatal dose.
- **Clinical Course:** The infant developed hypothermia, cyanosis, abdominal distension, and ashen-gray skin. These symptoms were consistent with *gray baby syndrome,* caused by chloramphenicol accumulation due to immature hepatic glucuronidation.
- **Outcome:** The antibiotic was discontinued, supportive therapy provided, and complete recovery occurred within four days.
- **Pharmacological Insight:** Neonates lack sufficient glucuronyl transferase activity, making chloramphenicol metabolism inefficient. Irrational high dosing causes toxic accumulation.
- **Source:** Lee KH, Kim JS. *A Case of Gray Syndrome. J Korean Pediatr Soc.* 1967;10(11):611–614.

Case 2 — Isoniazid-Induced Acute Hepatotoxicity

- **Patient:** 53-year-old male undergoing standard anti-tubercular therapy (isoniazid, rifampicin, pyrazinamide, ethambutol).
- **Irrational Use:** Continued therapy despite elevated liver enzymes and early signs of hepatotoxicity.
- **Clinical Course:** The patient developed jaundice, right upper-quadrant pain, and fatigue. Laboratory evaluation revealed markedly elevated AST and ALT levels. Diagnosis: *isoniazid-induced acute liver failure*.
- **Outcome:** Isoniazid was discontinued; patient required intensive care and recovered with supportive management.
- **Pharmacological Insight:** Failure to perform routine liver function tests and to stop hepatotoxic drugs promptly exemplifies irrational pharmacological monitoring.
- **Source:** Kabbara WK et al. *Acute and Fatal Isoniazid-Induced Hepatotoxicity: A Case Report.* (PMCID available).

Case 3 — Aminoglycoside-Induced Nephrotoxicity in Hospitalized Patients

- **Patients:** Multiple ICU patients (including pediatric and adult) treated with gentamicin or amikacin for sepsis.

- **Irrational Use:** Prolonged aminoglycoside therapy without therapeutic drug monitoring (TDM) or renal adjustment.
- **Clinical Course:** Patients developed acute kidney injury (non-oliguric renal failure) with increased serum creatinine. Some required temporary dialysis.
- **Outcome:** Partial or full renal recovery after drug discontinuation; several experienced long-term renal impairment.
- **Pharmacological Insight:** Aminoglycosides accumulate in proximal tubular cells, causing oxidative stress and necrosis. Irrational repeated or high dosing magnifies nephrotoxicity risk.
- **Sources:**
- Mingeot-Leclercq MP, Tulkens PM. *Aminoglycosides: Nephrotoxicity. Antimicrob Agents Chemother.*
- McWilliam SJ et al. *Aminoglycoside-Induced Nephrotoxicity in Children. Paediatr Int Child Health.* 2016.

Case 4 — Fluoroquinolone-Associated Tendon Rupture

- **Patients:** Elderly adults (≥65 years) on ciprofloxacin or levofloxacin therapy for urinary infections.
- **Irrational Use:** Extended treatment durations despite mild infections; many were also receiving corticosteroids.
- **Clinical Course:** Sudden onset of Achilles or iliopsoas tendon pain followed by rupture during routine activity.
- **Outcome:** Surgical repair required in several cases; functional recovery incomplete in some patients.
- **Pharmacological Insight:** Fluoroquinolones disrupt collagen synthesis and induce oxidative damage in tendon tissue. Risk is heightened by age and steroid co-administration.
- **Sources:**
- Smith N et al. *Ciprofloxacin-Associated Bilateral Iliopsoas Tendon Rupture. Age Ageing.* 2016.
- Kim GK. *Fluoroquinolone-Induced Tendinopathy and Tendon Rupture: A Systematic Review. J Antimicrob Chemother.* 2010.

Case 5 — Clostridioides difficile Colitis after Broad-Spectrum Antibiotic Use

- **Patient:** Adult woman treated empirically with ceftriaxone and clindamycin for mild respiratory illness.
- **Irrational Use:** Unnecessary broad-spectrum antibiotic therapy without bacterial confirmation.
- **Clinical Course:** Within ten days, the patient developed severe watery diarrhea, abdominal pain, and dehydration. Stool toxin assay confirmed *C. difficile* infection. Colonoscopy revealed pseudomembranous colitis.
- **Outcome:** Managed with oral vancomycin; complete recovery after three weeks.
- **Pharmacological Insight:** Broad-spectrum antibiotic misuse disrupts gut microbiota, allowing *C. difficile* overgrowth and toxin-mediated mucosal injury.
- **Sources:**
- Iwashita Y et al. *Community-Acquired Clostridioides difficile Infection. BMJ Case Rep.* 2024.
- Alnajjar LI et al. *Antibiotic-Associated Clostridium difficile Infection: A Case Report. PubMed.* 2023.

Case 6 — Linezolid-Induced Myelosuppression

- **Patient:** 94-year-old woman treated with linezolid for vancomycin-resistant *Enterococcus* infection.
- **Irrational Use:** Extended therapy (4 weeks) without hematological monitoring.

- **Clinical Course:** Developed severe thrombocytopenia and anemia; bone marrow suppression confirmed on examination.
- **Outcome:** Rapid hematological recovery after discontinuing linezolid; patient required transfusion support.
- **Pharmacological Insight:** Linezolid interferes with mitochondrial protein synthesis, suppressing bone marrow function when used longer than 14 days.
- **Sources:**
- Jordan K et al. *Linezolid-Induced Myelosuppression: Case Report. Ann Intern Med.* 2024.
- Wang MG et al. *Reversible Recurrent Profound Thrombocytopenia due to Linezolid. Case Rep.* 2022.

DISCUSSION:

Irrational use of antibiotics is a serious problem of universal public health, which causes adverse drug reactions, antimicrobial resistance, higher healthcare expenses, and poor patient outcomes. Antibiotics are commonly misused or abused even though one has clear treatment guidelines that can be used because there is uncertainty in the diagnosis, patient expectations, ignorance, and insufficient regulatory control. The case studies used in this review make it obvious that the outcomes of irrational usage of antibiotics are disastrous. Improper dosage of chloramphenicol in the neonates caused gray baby syndrome because of the immature hepatic metabolism. This brings out the significance of age-specific dosing and pharmacokinetics. In the same case, isoniazid should not be continued with high liver enzymes because this is a symptom of failure in therapeutic monitoring, which causes acute hepatotoxicity. This and similar cases make it obvious that irrationality is not restricted to the false choice of the drug only but also inappropriate monitoring and intervention. The nephrotoxicity caused by aminoglycoside and tendon rupture caused by fluoroquinolone also indicate the risks of long-term treatment and failure to adjust the dose. All these negative outcomes can be anticipated and avoided in cases of rational use of antibiotics with therapeutic drug monitoring and therapeutic courses. This overuse of broad-spectrum antibiotics, in the form of Clostridioides difficile colitis development, highlights how unproductive exposure to antibiotics takes a toll on normal microbiota and exposes the patient to serious secondary infections. Also, improper use of the reserve antibiotics like linezolid without hematologic surveillance in the long term represents poor antimicrobial stewardship. These practices speed up the development of resistance and restrict the future treatment choices. All these cases show that the most affected population groups are the vulnerable groups, including neonates, the elderly, and most critically ill patients, due to irrational use of antibiotics. In terms of public health, the irrational use of antibiotics fosters antimicrobial resistance, which results in treatment failure, prolonged length of hospitalization, and mortality. The cost of resistant infections is more expensive and toxic and an extra burden on the healthcare system, especially in low- and middle-income countries. Hence, the rational use of antibiotics, compliance with treatment regimes, periodic monitoring, and antimicrobial stewardship initiatives are necessary to put a check on this rapidly increasing crisis.

CONCLUSION:

Indiscriminate usage of antibiotics is a significant health problem across the world, which is equally contributing to adverse drug reactions, antimicrobial resistance, treatment failure, and raising the cost of healthcare. Poor prescribing habits that include the wrong choice of drugs, overdose, long periods of treatment, self-medication, and failure to monitor therapy have resulted in serious and even fatal effects. The case studies presented in this review are very clear in demonstrating how irrational use of antibiotics may lead to organ toxicity, secondary infections, and avoidable morbidity in various patient populations. It is important to learn the classification, mechanisms of action, and first-line treatment guidelines of antibiotics that are disease-specific in order to ensure the use of rational drugs. More care should be paid to vulnerable groups, including neonates, elderly patients, and critically ill people, as in this case, the consequences of the misuse of antibiotics can be devastating. The most effective way to reduce adverse effects and maintain antibiotic efficacy is a rational approach to prescribing antibiotics with the help of microbiological evidence, therapeutic drug surveillance, and compliance with clinical guidelines. The use of antimicrobial stewardship programs, consistent medical education, stringent regulatory responses, and awareness campaigns among the population should be used to combat irrational application of antibiotics. Healthcare professionals can make an important contribution by encouraging responsible use of antibiotics to prevent antimicrobial resistance and making the treatment of infectious diseases safe, effective, and sustainable.

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