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Review Article

Excessive antiseptic use: Is there any potential link with microbiome disturbance and possible antimicrobial resistance

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Abstract

Antiseptics have been important in the fight against infectious illnesses, particularly during the COVID-19 pandemic, when antiseptic use skyrocketed globally. Although they are still essential for preventing infections, antiseptics' overuse and carelessness might initiate issues with microbiome disruption. Several recent investigations indicate that excessive use of antiseptics affects the delicate balance of the gut, mouth, and skin microbiota and may potentially cause cross-resistance of pathogenic bacteria. Presently, there is not enough clear clinical evidence to support this claim. The necessity of balanced hygiene practices is underscored in this article. This article discusses possible consequences of antiseptic overuse associated with microbiome disturbance, the mechanism of resistance, public health implications, and information gaps.

Keywords: Antiseptic use, Microbiome, Antimicrobial Resistance, Infection

Access this article online

Introduction

Antimicrobial resistance (AMR) has emerged as a global public health concern of the twenty-first century (**Figure 2**), so preventing its future development and spread has been given priority in global public health[1]. It is acknowledged that the development of AMR to antibiotics is significantly influenced by the misuse, overuse, or abuse of antimicrobial medications in clinical settings, in livestock or aquaculture, or for the treatment of pets[2] (**Figure 1**).

Governments, local communities, and public health organizations started antiseptic usage in public buildings and communal places in response to the recent global spread of the coronavirus. Chemical disinfectants have been widely employed to sanitize public areas and prevent infection as a result of the COVID-19 epidemic[3]. A recent study found that the coronavirus can live on surfaces, including cardboard, plastic, and stainless steel, for up to three days and for up to three hours in the air. The Centers for Disease Control (CDC) recommends cleaning and sanitizing high-touch surfaces at least once a day, even if you are not leaving the house. This is because every time items or people enter and depart their houses, there is a chance of contamination[4].

It is common for antiseptics to be misused, abused, and used at high concentrations. Though cleaning and disinfecting properly can help avoid COVID-19, asthma, and other illnesses can develop in those who use these products and those who are highly sensitive to them. Antiseptic medication used for the mouth might cause cancer if overexposed, or it can be detrimental to reproductive health. Some of them damage the body's skin or other tissues[5].

In the fight against infectious illnesses, hygiene is still one of the most effective strategies. The prevalence of infections has been considerably decreased in both hospital and community settings since the invention and broad use of antiseptics, such as triclosan, chlorhexidine, alcohol-based hand sanitizers, and quaternary ammonium compounds. However, the COVID-19 pandemic led to unprecedented levels of antiseptic use, extending beyond clinical necessity in daily routine life. In addition to their intended antibacterial effects, antiseptics have the potential to alter the balance of human microbiota.

Figure 1: Common causes that potentially promote antimicrobial resistance

Methods

This perspective was conducted to find out the association between excessive antiseptic use, microbiome disturbance, and the development of antimicrobial resistance. A comprehensive literature search was performed using electronic databases, including PubMed, Scopus, Web of Science, Google Scholar, and educational websites. To find relevant articles, the search was conducted using keywords including "antiseptic overuse," "consequences of antiseptic overuse," "causes of dysbiosis," "mechanism of antimicrobial resistance," "antiseptic usage during COVID-19," and "hygiene products. Research and review articles published in English are thoroughly analyzed and summarized. Descriptive synthesis of the results was done to show trends and biological plausibility across studies. Preprints, conferences, and non-English literature were in the exclusion list. Risk-bias assessment was not applied to this short analysis.

Discussion

Excessive Use of Antiseptics

Coronaviruses can survive for several hours to days on surfaces made of plastic, glass, and metal. The usage of disinfectants has dramatically increased in an effort to control the transmission chain. According to recent research, the increased use of detergents and disinfectants during the COVID-19 epidemic caused 41.4% of the population to have health issues in at least one organ (skin dryness, preoccupation, skin itching, coughing, hand redness, headache, eye itching, lung and throat burning)[6]. Additionally, another study's findings showed that increasing exposure to bleach (42%), hand sanitizers (25%), chlorine gas (21%), and chloramine gas (2%) has resulted in a sharp rise in calls to poison centers and medical attention[7].

Antiseptics Type

The global surge in antiseptic usage during COVID-19 revealed a pattern of long-term habitual use of different types of antiseptics (**Table 1**) that extends well beyond clinical indications[8].

According to their chemical makeup, antiseptics are substances that either eradicate or inhibit the development of bacteria on the skin, hair, and wounded site[9].

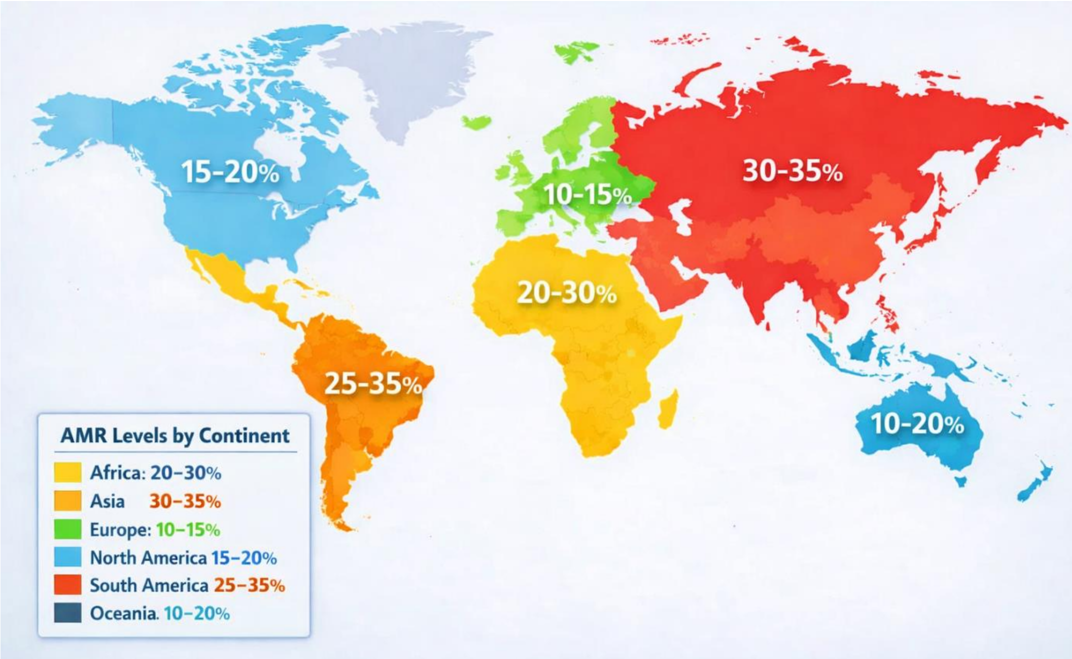

Figure 2: Approximate global distribution of antimicrobial resistance (AMR) by continent. Estimates are derived from global surveillance data and published reports from the World Health Organization and related global studies[50, 51]

Antiseptic Overuse and Microbiome Disturbance

Overuse of antimicrobial agents can disrupt the body's beneficial microbiota, or microbiome, and might cause dysbiosis (**Figure 3**). Immune system performance, metabolism, and vulnerability to infections, metabolic syndrome, and chronic inflammatory diseases may all be negatively impacted by this imbalance. With possible substitutes like probiotics or essential oils for long-term usage in some applications, a balanced strategy that maintains microbial ecosystems is required, even if antiseptics are crucial for emergency disease control[10]. Antiseptics, such as mouthwashes and hand sanitizers, are not specific to certain microbes and can potentially destroy both pathogens and good bacteria[11]. The general function of the gut may be hampered by the rise of some dangerous bacteria, such as Staphylococcus, caused by alteration of the gut microbiome[10]. The immune system can be weakened by disruption of the microbiome, especially the gut microbiome, which lowers the production of NLRC4, an important immune regulator 10. The metabolism can be adversely affected by microbiome dysbiosis, which may raise the risk of metabolic diseases such as fatty liver disease and type-2 diabetes[12]. Research indicates that excessive use of antiseptics is linked to systemic problems, such as high blood pressure and abnormalities in the metabolism of nitric oxide[11]. Regular use of antiseptic mouthwashes can destroy good oral bacteria, which might result in gingivitis, dental cavities, or even systemic consequences through a process mediated by the microbiota.

It has been claimed that overuse of hand sanitizers destroys symbiotic bacteria on the skin and digestive tract. As a result, there would be an imbalance between good and bad microorganisms[13]. This may contribute to intestinal symptoms (abdominal pain and diarrhea), inflammatory bowel disease[14], obesity[15], liver disease, chronic heart disease[16], autism[17], and colorectal cancer[18].

Table 1: Common antiseptic types and usage

Type of Antiseptic	Examples	Common Use
Alcohol based	Ethanol, isopropyl alcohol	Hand sanitizers, aftershaves, and cleaning minor wounds
Essential oil-based	Tea tree oil, Eucalyptus oil, Neem oil	Acne therapy, shaving irritation alleviation, and beard growth
Chlorhexidine	Chlorhexidine gluconate	Body wash, skin disinfectant before shaving or surgery
Hydrogen peroxide	3% H_2O_2 solution	Disinfecting cuts, oral rinses for gum health
Phenolic compound	Hexachlorophene	Deodorants, shaving gels, and antiseptic soaps
Quaternary ammonium compounds	Benzalkonium chloride	Wipes for intimate hygiene, skin, and aftershave
Iodine compound	Tincture, betadine, solution	Cleaning wounds, shaving cuts, and minor infections
Triclosan compound	Triclosan	Used to reduce bacterial growth on skin, control body odor, and prevent gum disease

Antiseptic Overuse and Antimicrobial Resistance

It is in dispute among the scientific community that antiseptics may promote the development of AMR, a process by which bacteria, viruses, fungi, and parasites adapt to withstand the action of antimicrobial medications. Although AMR results from naturally occurring genetic alterations in pathogens, the overuse and widespread abuse of many life-saving medications and chemicals in people, animals, and plants can accelerate its spread[19, 20]. Antiseptics kill bacteria that are susceptible to them, but they leave resistant germs alive and allow them to proliferate[21]. Microorganisms can become resistant to antimicrobials by acquiring new genetic features from other bacteria or developing them themselves over time[19, 20]. Microbes, especially bacteria, are very adaptive. Too much antiseptic exposure might cause genetic alterations or activate genes that give antibiotic resistance[22]. According to studies, certain antiseptics can cause bacteria to develop resistance mechanisms that shield them against antibiotics. For instance, triggering the SOS reaction in response to disinfectant-induced DNA damage can reduce membrane permeability and trigger efflux pumps, which can release antibiotics and disinfectants[23]. Excessive use of antiseptics can cause resistant microorganisms to accumulate in the environment, which can spread to affect other types of bacteria[24].

Table 2: Overview of antiseptic overuse is linked with microbial disturbance

Commonly Overused Antiseptics	Possible Mechanisms of Microbial Adaptation	Cross-Resistance with Antibiotics	Risk Factors for Overuse	Clinical Impact
Chlorhexidine, Triclosan, Benzalkonium chloride (quaternary ammonium compounds), Povidone-iodine, Alcohol-based agents	Efflux pump activation (e.g., qac genes in bacteria), mutations in target sites, and biofilm formation protect microbes from antiseptics	Antibiotics may also be expelled by efflux pumps caused by exposure to antiseptics; selection of multidrug-resistant strains	Excessive use in consumer products (soaps, mouthwashes, hand sanitizers), inadequate contact time, or improper dilution leading to sub-lethal exposure	Adaptation of pathogens on surfaces and skin, reduced wound care, and irritation in the wound and surgical site

Antiseptic tolerance has been demonstrated by bacteria, including Staphylococcus aureus and Pseudomonas aeruginosa[25]. The broad-spectrum mechanism of efflux pumps allows bacteria be resistant to antimicrobial agents (**Table 2**). In the presence of these various substances, efflux pumps create a protective barrier that promotes multidrug resistance and boosts bacterial survival by bringing the intracellular concentration of these agents below fatal thresholds[26]. Bacterial population may adapt and survive when exposed to antiseptics at low doses or in sublethal levels.

Table 3. Different alternative approaches to combating antimicrobial resistance (AMR)

Strategy	Process	Benefits	Limitations
Antimicrobial Stewardship	Optimized and rational use of antimicrobials in humans and animals to reduce selective pressure	Reduces resistance development; cost-effective; improves patient outcomes	Requires strong healthcare systems and compliance
Phage Therapy	Use of bacteriophages to specifically infect and lyse bacterial pathogens	High specificity; minimal impact on normal microbiota	Narrow host range; regulatory and manufacturing challenges
Antimicrobial Peptides (AMPs)	Short peptides that disrupt bacterial membranes or intracellular targets	Broad-spectrum activity; low resistance potential	Toxicity, stability, and delivery issues
CRISPR-Cas–Based Approaches	Gene-editing systems used to selectively eliminate resistance genes	High precision; customizable	Delivery system challenges
Combination Therapies	Use of multiple agents (antibiotic–antibiotic or antibiotic–adjuvant)	Synergistic effects; delays resistance	Increased toxicity; complex dosing
Anti-virulence Therapies	Target bacterial virulence factors rather than bacterial viability	Lower selective pressure for resistance	May not clear infection alone
Nanotechnology-Based Approaches	Nanoparticles used to enhance drug delivery or exert direct antimicrobial effects	Improved bioavailability	Systemic toxicity
Public Awareness	Encouraging the use of antibiotics, good hygiene, and resistance awareness	Lowers the need for and abuse of unnecessary antibiotics	Behavior change takes time, requires constant work, and has an impact that is difficult to assess
Protecting Environment	Lowering the use of antibiotics in industry and agriculture to stop the spread of resistance	Decreases selection pressure for resistance	Poor enforcement of regulations, international cooperation, and economic ramifications

Mechanism of AMR by microbes: Poor hygiene and inadequate sanitation contribute to the spread of infectious illnesses, which increases the need for antibiotics and leads to the emergence of resistance. Lastly, low-quality drugs can not contain enough active ingredients or the right dosage, which might lead to inadequate treatment and the emergence of resistance. In order to resist the antibacterial effects of once-effective drugs used to cure ailments, microorganisms have evolved a variety of clever defenses. These defense mechanisms allow microbes to withstand the effects of antibiotics and other antimicrobial substances. Through structural changes and the use of tactical metabolic pathways, bacteria and other parasites exhibit extraordinary adaptation mechanisms that allow them to ignore or neutralize antimicrobial agents[24, 27, 28]. Typical resistance mechanisms include the following: modifying binding sites like ribosomes to decrease drug effectiveness; restricting the entry of antibiotics into cells to prevent their accumulation; enzymatic modification or degradation of antibiotics; and increasing the activity of efflux pumps that remove antibiotics from cells before they can reach adequate levels (**Figure 4**)[29]. Additionally, bacteria can form surface-bound colonies called biofilms that have different nutritional needs and little resistance to antibiotics [30]. The bacteria are further protected by these biofilms. Furthermore, plasmids and other mobile genetic components enable horizontal gene transfer, which allows bacteria to acquire resistance genes from neighboring cells or even different species[31].

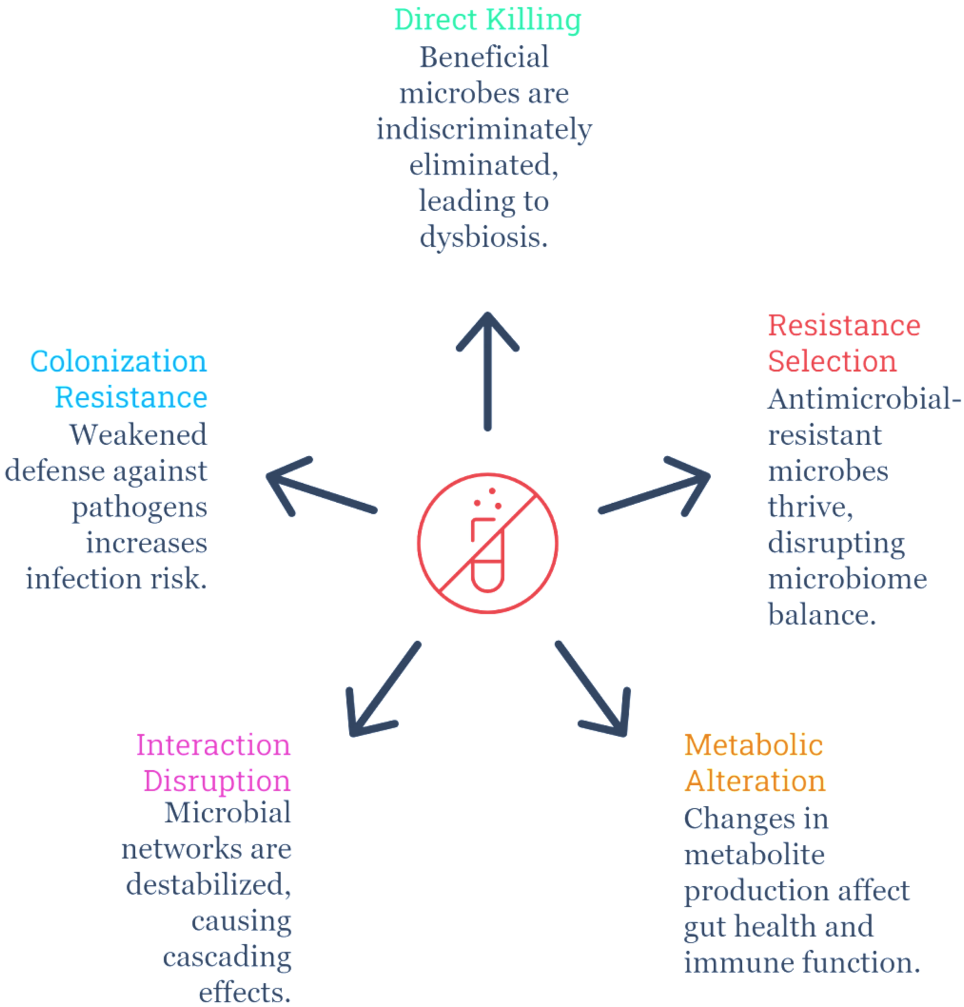

Figure 3: Possible consequences of antimicrobial overuse

The overuse and abuse of antimicrobial agents is the primary cause of AMR. Sensitive microorganisms are eliminated when antibiotics are used, but resistant microbes endure. Random genetic alterations or preexisting characteristics are the source of these resistant bacteria. Through horizontal gene transfer techniques like conjugation, transformation, and transduction, they can disseminate these resistance traits. As a result, resistance within bacterial populations spreads more quickly (**Figure 5**). Multidrug-resistant strains develop as a result of this process over time. Treatment failure, recurring infections, and increased transmission in communities and healthcare settings can result from this.

Over the past few decades, several bacteria have evolved AMR through different approaches[32]. Methicillin-resistant *Staphylococcus aureus* develops resistance to many drugs, including methicillin, via means of horizontal gene transfer and mutations in the mecA and mecC genes[33]. *Escherichia coli* and *Klebsiella pneumoniae* are examples of carbapenem-resistant Enterobacteriaceae that have acquired carbapenemase genes, making them resistant to carbapenem medications[34]. These genes are frequently carried on plasmids, which makes it easier for bacteria to spread them. ESBL genes, frequently produced by plasmids, give the ESBL-producing E. coli resistance to a wide range of antibiotics, including cephalosporins and penicillins. Many anti-TB drugs cannot affect MDR of *Mycobacterium tuberculosis* because of mutations in their DNA[35]. Due to a combination of mutations and the acquisition of resistance genes, *Acinetobacter baumannii* has become resistant to some antibiotics[36]. Front-line medicines used to treat gonorrhea are ineffective against multidrug-resistant *Neisseria gonorrhoeae*[37]. High-risk populations have been plagued by opportunistic oral and vaginal infections caused by fluconazole-resistant Candida fungus[38].

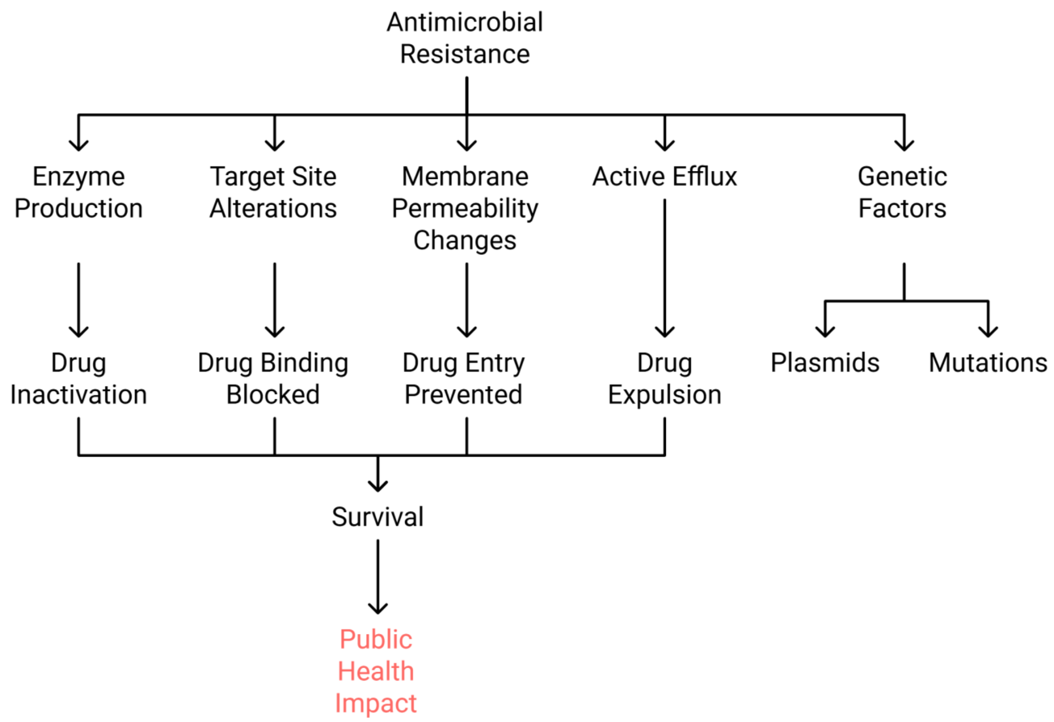

Figure 4: Process of how antimicrobial resistance develops in bacteria

Difficulties in mitigating antimicrobial resistance: Addressing the emergence of antimicrobial resistance (AMR) involves multifaceted challenges with no straightforward solutions. Efforts to curb the extensive use of antimicrobials are hindered by their entrenched roles in healthcare systems and the economic frameworks of animal food production[39]. Modern agricultural systems rely on the routine administration of antimicrobials to animals for infection prevention and growth promotion, while doctors frequently rely on antibiotic prescriptions to protect against bacterial infections due to the lack of quick point-of-care diagnostics. Despite knowledge of the hazards of antibiotic resistance linked to misuse, antimicrobial stewardship programs in healthcare and revised animal husbandry rules are still not widely implemented.

These problems are made worse by the antibiotic drug development pipeline's inability to keep up with MDR bacteria's ongoing evolution. Costly antimicrobial research with few financial incentives is being abandoned by pharmaceutical corporations more often. Furthermore, although legislative changes that finance the development of antibiotics represent progress, given the length of phase trials, short-term solutions appear doubtful[40]. International cooperation on AMR surveillance and stewardship standards is still fragile, which further impedes containment efforts even while agencies like the UN, WHO, and CDC acknowledge the disease's transboundary threats. Novel resistance variables can evolve locally and spread globally due to varying availability to high-quality diagnostics and antibiotic supervision across nations. Localized development may be continuously undermined and negated by areas of poor governance. In the end, the distinct "tragedy of the commons" character of antibiotic resistance necessitates shared accountability, a fair, and cooperative international response. However, agreement on legally binding international laws and financial sources that are necessary to improve antimicrobial stewardship and innovation globally is still hampered by geopolitical issues[41, 42].

Healthcare workers need to be up to date on infection prevention, control, and antimicrobial stewardship procedures. Establishing policies, educating medical staff, and putting procedures in place to ensure the prudent use of antibiotics are all parts of antibiotic stewardship in hospital settings. On the other hand, antibiotic stewardship in outpatient settings focuses on patient education, diagnostic testing, and encouraging the use of antibiotics only when absolutely required. It is feasible to lessen the selection pressure placed on microbes and so slow the development of antibiotic resistance by creating a culture that encourages the prudent use of antibiotics. Details of several different approaches to combating antibiotic resistance are shown in (**Table 3**).

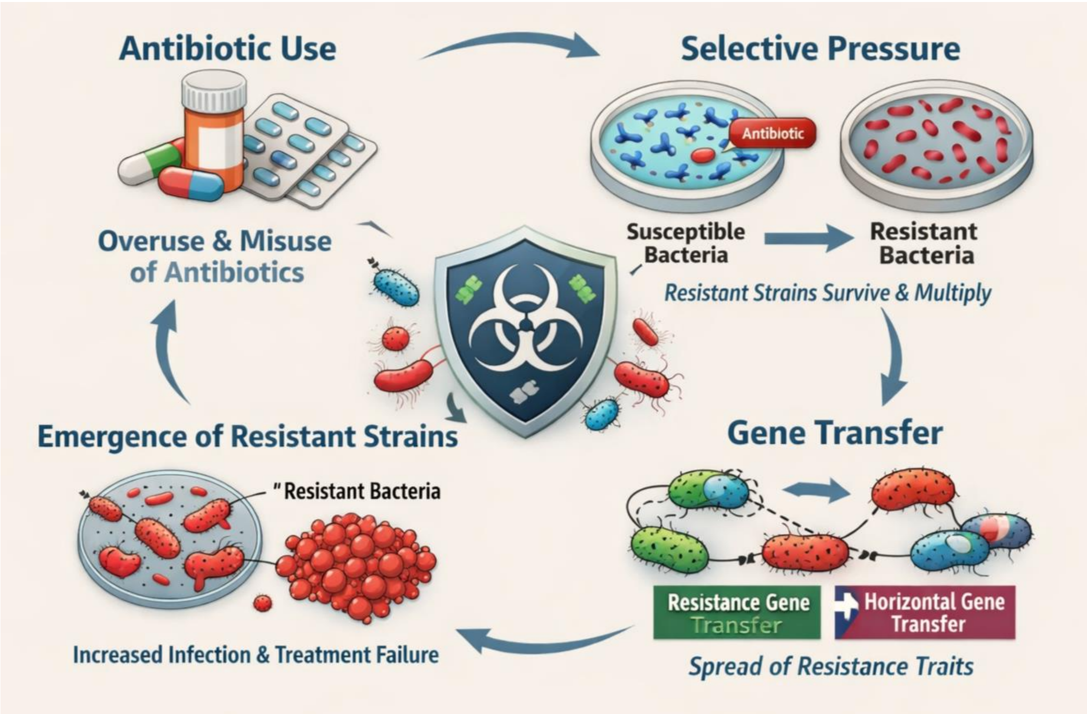

Figure 5: Development of antimicrobial resistance for antibiotic overuse

Downside of AMR: The rise of resistant bacteria, viruses, fungi, and parasites significantly lowers the effectiveness of standard therapies. This leads to longer illnesses, increased suffering and death, and a higher risk of complications. Infections from multidrug-resistant organisms often need more expensive, toxic, or less effective second- and third-line treatments. This raises healthcare costs and creates a heavy financial burden on patients and healthcare systems[41, 43]. Antimicrobial resistance also compromises the safety of standard medical procedures that heavily depend on efficient prevention and treatment, such as organ transplants, chemotherapy, surgery, and critical care. The emergence of "superbugs" is accelerated by the spread of resistance genes through gene transfer, which reduces treatment options and increases the possibility of treatment failure[44, 45]. The repercussions are particularly severe in low- and middle-income nations, where access to new antimicrobials and diagnostic resources is limited. Antimicrobial resistance has the potential to reverse the advancements of contemporary medicine, transforming once-treatable infections into fatal illnesses and endangering the security of the world's health if this problem is not addressed.

Public Health Implications

- **Healthcare costs**
  Increased cases of resistant infections burden healthcare systems and increase medical costs.
- **Vulnerable population**
  Children, the elderly, and immunocompromised individuals may be disproportionately affected.
- **Global inequality**
  Low and middle-income countries lack proper surveillance of antiseptic use, making the threat difficult to monitor.
- **Long-term risk**
  Immune dysregulation caused by a disturbed microbiota may affect the onset of chronic diseases.

Future Directions and Information Gap

Microbiome-friendly hygiene means using products and methods that support the natural equilibrium and diversity of microorganisms within the body, rather than disrupting them with harsh chemicals or over-cleansing. This strategy emphasizes the importance of keeping the helpful bacteria and other microbes found on the skin, gut, and other areas of the body that serve as a protective layer and are crucial for overall well-being[46]. Awareness initiatives aimed at reducing the excessive and unnecessary use of antiseptics should be promoted. Funding organizations need to allocate adequate resources for both the creation and utilization, as well as for assessing the impact of these awareness efforts. Professionals in health communication, social marketing, and infectious diseases ought to participate in the design and execution of these awareness campaigns[47]. Balance between infection prevention and preservation of healthy microbial diversity by rational use of antiseptics is important[48]. A campaign to raise public awareness is essential for controlling and avoiding infection epidemics[49].

There is no exact evidence of antimicrobial resistance development due to overuse of antiseptics; however, advanced research about this topic on a sufficient number of populations is required. There is a knowledge gap among the general populace due to a few reasons, including insufficient data linking chronic antiseptic use with microbiome alterations across populations, few long-term studies evaluating health outcomes among different age groups, and limited research in developing countries despite the high burden of infectious diseases.

Conclusion

Although antiseptics are still crucial for preventing infections, using them excessively can pose unintended health hazards. Research is ongoing about long-term public health issues, and for evidence that there is a probable link between the overuse of these antiseptic agents and microbiome disruptions and antibiotic resistance. Several studies are needed to demonstrate any potential connection between antimicrobial resistance and antiseptic overuse. Overall, to protect human health, a balanced strategy that combines sensible antiseptic usage, innovation in microbiome-friendly hygiene products, and robust surveillance systems is required. Thus, it seems imperative to educate the general public about the possible risks associated with the excessive use of antiseptics.

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