Drug Repurposing in Infectious Diseases: A Promising Strategy for Rapid Therapeutic Development

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***Abstract*—The escalating threat of antimicrobial resistance (AMR) and the emergence of novel viral pathogens necessitate the development of rapid therapeutic strategies. Traditional drug discovery is characterized by high costs and protracted timelines. Drug repurposing (DR), or repositioning, offers an alternative by utilizing existing, approved medications for new clinical indications. This review provides a comprehensive analysis of DR in the context of infectious diseases, exploring computational methodologies, artificial intelligence (AI), and pharmacological synergy. We discuss the transition from phenotypic screening to network-based pharmacology and provide detailed case studies of repurposed agents in viral, bacterial, and parasitic infections. Finally, we address the regulatory and economic landscapes that influence the adoption of repurposed drugs in global healthcare.**

***Index Terms*—Antimicrobial resistance, Artificial Intelligence, Drug repurposing, Infectious diseases, IMRAD Pharmacology.**

I. INTRODUCTION

Infectious diseases remain a primary cause of global morbidity, complicated by the rapid evolution of pathogens. The traditional "de novo" drug development process is often cited as a 12-to-15-year journey with a price tag exceeding $2.5 billion per successful molecule. For infectious diseases—especially those with pandemic potential—this timeline is unacceptably slow.

Drug repurposing (DR) leverages existing safety, pharmacokinetic, and toxicological data of approved drugs, potentially reducing the development timeline to 3–6 years. By bypassing early-phase safety trials, DR presents a cost-effective and low-risk pathway to clinical application. This review explores the mechanisms, tools, and recent breakthroughs in DR specifically aimed at viral, bacterial, and neglected parasitic diseases.

II. METHODOLOGY

This research review is based on a systematic analysis of peer-reviewed literature published between 2020 and 2025. Databases including PubMed, ScienceDirect, and Google Scholar were queried using terms such as "Drug Repositioning," "AI in Drug Discovery," and "Infectious Disease Therapeutics." Over 20 key references were synthesized to provide an up-to-date perspective on the field, focusing on computational advancements and clinical outcomes.

III. MECHANISMS OF DRUG REPURPOSING

The biological basis for DR lies in polypharmacology—the ability of a single drug molecule to interact with multiple biological targets. This is often categorized into two main streams:

3.1. On-Target Repurposing

In on-target repurposing, the known primary target of a drug is found to be relevant to a different disease. A classic example in infectious diseases is the use of viral polymerase inhibitors developed for one virus (e.g., Ebola) against another (e.g., SARS-CoV-2).

3.2. Off-Target Repurposing

Off-target repurposing involves identifying a previously unknown interaction between a drug and a biological pathway. This is often facilitated by high-throughput screening or computational docking

studies where "old" drugs are tested against new pathogen proteins.

IV. COMPUTATIONAL ADVANCEMENTS AND ARTIFICIAL INTELLIGENCE

The integration of Artificial Intelligence (AI) has revolutionized the identification of repurposable candidates.

Machine Learning (ML) models can now predict drug-target interactions (DTI) with high precision by analyzing massive datasets of molecular structures and biological networks.

4.1. Deep Learning in Drug Discovery

Graph Neural Networks (GNNs) are particularly effective at modeling the complex interactions between host proteins and pathogen proteins. By identifying "hubs" in these networks, AI can suggest which existing drugs might disrupt the infection cycle.

4.2. Network Pharmacology

Rather than looking at a single drug-target pair, network pharmacology examines the entire system. This holistic approach helps in predicting side effects and synergistic combinations that might not be apparent through traditional methods.

V. APPLICATIONS IN INFECTIOUS DISEASES

5.1. Viral Infections

Viral outbreaks require immediate responses. During the COVID-19 pandemic, drugs like Remdesivir and Baricitinib were rapidly repurposed. Ongoing research is looking at broad-spectrum antivirals that can be deployed against future "Disease X" pathogens.

5.2. Bacterial Infections and AMR

The "antibiotic pipeline" is drying up. Repurposing non-antibiotic drugs (e.g., antidepressants, statins) that possess secondary antimicrobial properties or efflux pump inhibitory effects is a growing area of study. For instance, certain NSAIDs have been shown to sensitize resistant *Staphylococcus aureus* to traditional antibiotics.

5.3. Parasitic and Neglected Tropical Diseases (NTDs)

NTDs often lack commercial incentive for new drug development. Repurposing existing veterinary medicines or cancer drugs for human parasitic infections (like Leishmaniasis or Malaria) provides a faster route to treatment

VI. ECONOMIC AND REGULATORY FRAMEWORKS

The economic benefit of DR is significant. The estimated cost for a repurposed drug is roughly *$300 million*, compared to *$2.5 billion* for a new entity. However, regulatory challenges include intellectual property (IP) issues, as many repurposed drugs are already off-patent, reducing the incentive for large pharmaceutical companies to fund expensive Phase III trials.

Table 1: Successful and Potential Repurposed Drugs in Infectious Diseases

Drug Name	Original Indication	Target Pathogen	Mechanism
Remdesivir	Ebola Virus	SARS-CoV-2	RNA Polymerase Inhibition
Niclosamide	Anthelmintic	Zika/COVID-19	Viral entry inhibition
Auranofin	Rheumatoid Arthritis	Amoebiasis	Thioredoxin reductase inhibitor
Disulfiram	Alcoholism	M. tuberculosis	Enzyme inhibition
Statins	Hypercholesterolemia	S. aureus	Biofilm disruption

VII. CHALLENGES AND LIMITATIONS

Despite the advantages, DR is not a "magic bullet." Challenges include:

Dosage Misalignment: The dose required for the new indication may be toxic.

IP Barriers: Lack of patent protection for older molecules.
Clinical Validation: In vitro success does not always translate to in vivo efficacy

VIII. CASE STUDY: COVID-19 AND BEYOND

The global response to SARS-CoV-2 demonstrated the power of international collaboration in DR. Programs like the WHO Solidarity Trial screened thousands of compounds, leading to the rapid adoption of life-saving immunomodulators and antivirals. Lessons learned here are now being applied to the fight against multi-drug resistant tuberculosis (MDR-TB).

IX. FUTURE PERSPECTIVES

The future of DR lies in "Personalized Repurposing," where genomic data of both the patient and the pathogen are used to select the most effective existing drug. Furthermore, the development of "Open-Source" drug discovery platforms may help overcome the IP hurdles associated with neglected diseases.

X. CONCLUSION

Drug repurposing represents a paradigm shift in how we approach infectious disease therapy. By combining established pharmacology with cutting-edge AI, we can significantly reduce the time and cost required to bring effective treatments to patients. While regulatory and scientific challenges persist, the success stories of the last decade suggest that DR will remain a cornerstone of global health security.

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