Antimicrobial Resistance and Tuberculosis: Emerging Threats and Strategies for Global Control

Syed Yunis Bukhari [1], MD Azad Alam [2], Aditya Kamboj[3], Ameen Heshmat Ali[4], Abrar Hussain Joo[5], Syed Tufail[6], Ritika Dadwal[7], Amandeep Kaur[8]

[1,2,3,4,5,6,7,8] *Department of Medical Laboratory Technology, University Institute of Allied Health Sciences (UIAHS), Chandigarh University, Punjab, India*

***Abstract*—Tuberculosis (TB), caused by Mycobacterium tuberculosis, remains one of the leading infectious killers globally. The emergence of antimicrobial resistance (AMR), particularly multi-drug resistant (MDR-TB) and extensively drug-resistant tuberculosis (XDR-TB), threatens decades of progress in TB control. Resistance arises primarily due to incomplete treatment, improper prescription, and spontaneous genetic mutations. This review summarizes current knowledge on AMR in tuberculosis, mechanisms of resistance, diagnostic challenges, treatment strategies, and the role of surveillance and stewardship programs. Integrating AMR control into global TB strategies is essential to prevent the spread of resistant strains and safeguard public health.**

***Index Terms*—Tuberculosis, Antimicrobial Resistance (AMR), MDR-TB, XDR-TB, Drug resistance, public health, WHO, Mycobacterium tuberculosis, Diagnosis, Treatment failure, Global health**

I. INTRODUCTION

Tuberculosis (TB) is an ancient disease that continues to pose a major health burden, with over 10.6 million new cases and 1.6 million deaths in 2023 according to the World Health Organization (WHO) [1]. The rise of antimicrobial resistance (AMR) the ability of microorganisms to resist previously effective drugs has exacerbated TB control challenges [2].

The emergence of multi-drug-resistant tuberculosis (MDR-TB), resistant to both isoniazid and rifampicin, and extensively drug-resistant tuberculosis (XDR-TB), resistant to fluoroquinolones and second-line injectable drugs, signifies the growing AMR crisis [3].

Addressing AMR in TB is not only a microbiological or pharmacological challenge but also a socio-economic and public health imperative. This review explores mechanisms, epidemiology, diagnostics, and control strategies of AMR in TB.

II. METHODOLOGY

A comprehensive literature review was performed using PubMed, Scopus, and ScienceDirect databases from 2010–2025. Search terms included "tuberculosis," "MDR-TB," "XDR-TB," "antimicrobial resistance," "diagnosis," and "drug susceptibility testing." Peer-reviewed articles, WHO and CDC reports, and national TB program data were included.

III. MECHANISMS OF ANTIMICROBIAL RESISTANCE IN TUBERCULOSIS

Resistance in Mycobacterium tuberculosis is primarily due to spontaneous chromosomal mutations rather than horizontal gene transfer [4]. Resistance emerges due to incomplete therapy, drug misuse, substandard drugs, and patient non-adherence [5],[6]. Major mechanisms include:

Drug Class	Key Drug	Gene Mutation Responsible	Mechanism of Resistance
Isoniazid	INH	katG, inhA	Impaired drug activation
Rifampicin	RIF	rpoB	RNA polymerase alteration
Ethambutol	EMB	embB	Cell wall synthesis inhibition loss
Pyrazinamide	PZA	pncA	Enzyme inactivation
Fluoroquinolones	Levofloxacin, Moxifloxacin	gyrA, gyrB	DNA gyrase alteration
Aminoglycosides	Amikacin, Kanamycin	rrs, eis	Ribosomal target modification

Table 1. *Gene Mutations and Mechanisms of Drug Resistance in Mycobacterium tuberculosis*

IV. GLOBAL BURDEN OF DRUG-RESISTANT TUBERCULOSIS

According to WHO's Global TB Report 2024, about 450,000 people developed MDR-TB worldwide, with the highest burden in India, China, and Russia [7]. Only 63% of MDR-TB cases were successfully treated [8].

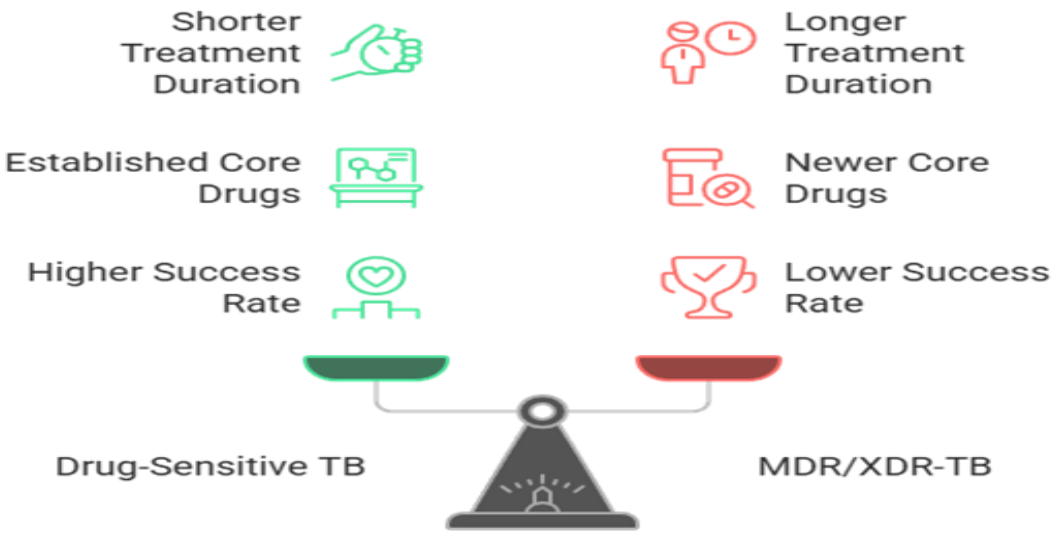
The rise of XDR-TB and pre-XDR-TB cases is alarming. In India alone, MDR-TB represents 27% of total TB burden, and XDR-TB accounts for 9–10% of MDR cases [9]. Weak laboratory networks, delayed diagnosis, and improper treatment regimens contribute to the AMR crisis in TB management [10],[11].

V. DIAGNOSTIC CHALLENGES

Conventional diagnostic methods like sputum microscopy and culture are time-consuming (up to 6–8 weeks) [12]. Newer molecular techniques like:

1. GeneXpert MTB/RIF (detects rifampicin resistance in 2 hours) [13].
2. Line Probe Assay (LPA) (detects MDR and XDR patterns) [14].
3. Whole Genome Sequencing (WGS) (offers comprehensive mutation mapping) are improving diagnosis. [15].
4. Limited access, cost, and lack of trained personnel hinder implementation in resource-poor settings [16]

VI. TREATMENT AND MANAGEMENT STRATEGIES



Current TB management follows WHO-recommended shorter MDR regimens combining bedaquiline, pretomanid, linezolid, and moxifloxacin [17]. Bedaquiline and delamanid have significantly improved MDR-TB outcomes [18]. However, resistance to these new drugs is emerging, highlighting the need for drug stewardship and pharmacovigilance [19].

	RECOMMENDED DURATION	CORE DRUGS	SUCCESS RATE
Drug-sensitive TB	6 months	INH, RIF, EMB, PZA	~85%
MDR-TB	9–12 months	BDQ, LZD, MFX, CFZ	~65%
XDR-TB	18–20 months	BDQ, PMD, LZD, DLM	~55%

Table 2. *Treatment Regimens and Success Rates for Different Types of Tuberculosis*

VII. INTEGRATION OF AMR SURVEILLANCE AND TB CONTROL

WHO's Global Antimicrobial Resistance and Use Surveillance System (GLASS) and India's National TB Elimination Program (NTEP) now emphasize integrated AMR surveillance for TB [20].

KEY STRATEGIES INCLUDE:

1. Strengthening molecular diagnostics and DST labs [21].
2. Regulating antibiotic sales and prescriptions [22].
3. Enhancing patient adherence and treatment completion through digital adherence technologies [23].
4. Integrating AMR awareness into medical and laboratory curricula [24].

VIII. DISCUSSION

AMR in TB is a complex interplay of microbial genetics, healthcare practices, and socio-economic determinants. Studies show that treatment interruptions, monotherapy, and drug shortages are major contributors to resistance [25].

Implementation of rapid diagnostics, new regimens, and community-based adherence programs has shown promising outcomes in reducing MDR-TB burden [26],[27].

However, antibiotic misuse in the general population, including over-the-counter fluoroquinolones, continues to select resistant Mycobacterium strains [28]. Public awareness, clinician training, and global policy coordination remain crucial pillars for AMR containment.

IX. CONCLUSION

AMR in tuberculosis represents a major obstacle to the WHO's goal of TB elimination by 2035. Addressing this challenge requires a multi-sectoral approach that combines rapid diagnostics, effective treatment regimens, surveillance systems, and global cooperation.

Educational institutions, particularly medical and laboratory science departments, play a key role in promoting awareness and responsible antibiotic use among future professionals. Combating AMR in TB today will determine the sustainability of global TB control tomorrow.

X. ACKNOWLEDGEMENTS

The author acknowledges the Department of Medical Laboratory Technology, UIAHS, Chandigarh University, for academic support.

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