

Commentary review on trends and emerging challenges of tuberculosis and drug resistance

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ABSTRACT: Despite strides in tuberculosis (TB) control, including advancements in medication, the ongoing challenge of drug-resistant TB continues to complicate global efforts to combat this infectious disease. This review aims to analyse current global trends in TB incidence and prevalence, assess the scope and impact of drug-resistant TB, and identify the emerging challenges in TB control and management. This review compiled and analysed studies from December 2001 to 6th September 2023 on tuberculosis and drug resistance, utilising comprehensive search strategies, inclusion criteria, and data extraction methods to provide conclusive insights. A total of (n=80) manuscripts were identified and retrieved for detailed evaluation during the short-listing of published literature and manuscripts. Following a thorough review of the published research papers and government database reports, n=42 were identified as appropriate and were considered for the present manuscript. The study revealed significant global trends in tuberculosis (TB) incidence and prevalence, with a historical decline in global TB incidence by an average of 1.6% per year since 2000. However, challenges related to healthcare infrastructure and resource allocation persist, hindering the scaling up of these technologies in high-burden regions where the incidence rates remain critically high. The findings also emphasise the growing challenge of drug-resistant TB, with multidrug-resistant tuberculosis (MDR-TB) and extensive drug-resistant tuberculosis (XDR-TB) posing significant treatment and public health challenges globally. Addressing the global TB epidemic and drug resistance requires a multi-faceted approach that includes strengthening healthcare systems through improved access to quality TB services, enhanced TB detection and diagnosis, scaled-up treatment and care, and effective management of drug resistance. TB and drug resistance continue to be significant global health challenges. Understanding the evolving trends and emerging challenges is crucial for developing effective strategies to control and eventually eliminate TB and mitigate the threat of drug-resistant strains.

Keywords: Diagnostics, drug resistance, trend, tuberculosis.

INTRODUCTION

Tuberculosis (TB) is a contagious disease caused by *Mycobacterium tuberculosis*, which is transmitted through the respiratory route. TB continues to be a major public health problem and is one of the top ten causes of death

worldwide (Abi *et al.*, 2023; Abi *et al.*, 2024). TB has afflicted humanity for millennia, with evidence of TB infection found in ancient Egyptian mummies. It became a major epidemic in Europe during the 18th and 19th

centuries, earning the nickname "consumption" due to its wasteful effects on the body. The discovery of antibiotics, particularly streptomycin, in the mid-20th century revolutionised TB treatment and led to significant declines in TB incidence in developed countries. Despite progress, TB remains a global health issue due to various factors, including poverty, malnutrition, crowded living conditions, and the HIV/AIDS pandemic (Zumla and Raviglione, 2013). TB is particularly prevalent in resource-limited settings, where healthcare infrastructure is often inadequate. The emergence of multidrug-resistant TB (MDR-TB) and extensively drug-resistant TB (XDR-TB) strains in the late 20th century complicated TB control efforts, as these strains are resistant to first-line and, in the case of XDR-TB, some second-line drugs (WHO, 2020; Zumla and Raviglione, 2013).

Multidrug-resistant tuberculosis (MDR-TB) and extensively drug-resistant tuberculosis (XDR-TB), as drug-resistant TB strains, have added a significant layer of complexity to TB control efforts. The primary driver of drug-resistant TB is the improper use of antibiotics to treat TB. When patients do not complete their full course of treatment, the TB bacteria that survive can develop resistance to the drugs used. This non-adherence can occur due to various reasons, including the long duration of treatment, side effects of medications, and socioeconomic factors that make it difficult for patients to access healthcare consistently. Weak healthcare systems in many TB-endemic regions can hinder the proper diagnosis and management of TB cases (Zumla and Raviglione, 2013; Dheda *et al.*, 2017). This includes a lack of access to quality diagnostics, trained healthcare personnel, and consistent drug supplies. These gaps contribute to the emergence of drug-resistant TB strains. In some cases, TB drugs are prescribed without proper diagnostic confirmation of TB infection. This can lead to inappropriate use of antibiotics and increase the risk of resistance development. Drug-resistant TB strains can be transmitted from person to person, especially in crowded and poorly ventilated settings such as prisons and healthcare facilities. This amplifies the spread of drug-resistant TB within communities (Zumla and Raviglione, 2013). People living with HIV are more susceptible to TB infection and are at greater risk of developing drug-resistant TB due to weakened immune systems. The synergy between TB and HIV epidemics has contributed to the rise of drug-resistant TB (WHO, 2021b). The movement of people across borders facilitates the spread of drug-resistant TB strains from one region to another. Travellers infected with drug-resistant TB can introduce these strains to new areas (Dheda *et al.*, 2017; O'Neill, 2016). Studying global trends and emerging challenges of TB is vital for several reasons:

Public health impact: TB remains one of the top infectious disease killers worldwide, with millions of new cases

and deaths each year. Understanding its trends helps allocate resources and plan interventions effectively.

Drug resistance mitigation: Monitoring and addressing the emergence of drug-resistant TB strains is crucial to preventing their further spread and ensuring effective treatment.

Health inequalities: TB disproportionately affects vulnerable populations, exacerbating health inequalities. Analysing trends can help identify disparities and tailor interventions to specific communities.

Innovative solutions: Research into emerging challenges can drive innovation in diagnostics, treatments, and vaccines to combat TB more effectively.

Global collaboration: TB is a global issue that requires international cooperation. Studying global trends fosters collaboration and the sharing of best practices among countries.

Therefore, this review aims to analyse global TB trends, assess the impact of drug-resistant TB, and identify emerging challenges in TB control and management.

METHODOLOGY

Study design

This review article synthesised and analysed existing literature on Tuberculosis and Drug Resistance. This method allows for a comprehensive evaluation of the current research available on the topic and enables the development of informed conclusions.

Data sources

A comprehensive search was conducted to identify relevant articles on Tuberculosis and Drug Resistance. Electronic databases, including PubMed, Medline, Scopus, Google Scholar, and Web of Science, were searched using predetermined keywords and Medical Subject Headings (MeSH) terms. Additional sources, such as reference lists of retrieved articles and relevant conference proceedings, were also searched to ensure inclusiveness.

Search strategy

The search strategy employed a combination of keywords and MeSH terms related to Tuberculosis and Drug Resistance. The following search terms were used:

"tuberculosis," "drug-resistant tuberculosis," "pulmonary tuberculosis," "extra-pulmonary tuberculosis," "tuberculosis treatment," "tuberculosis diagnosis," "tuberculosis prevention," "tuberculosis challenges," and "tuberculosis control." The search was limited to articles published in the English language.

Selection criteria

The inclusion criteria included: (a) studies reporting original data on Tuberculosis, (b) studies published in peer-reviewed journals, (c) studies written in the English language, and (d) studies focusing on human populations. Studies that primarily focused on other diseases or did not provide relevant data related to Tuberculosis were excluded. The review compiled and analysed studies from December 2001 to 6th September 2023.

Data extraction

Five independent reviewers conducted the data extraction process using a standardised form. Data extracted from selected studies included study design, sample size, participant characteristics, intervention or exposure details, outcome measures, and main findings. Any discrepancies in data extraction were resolved through discussion and consultation with the group of reviewers.

Limitations of the Study

One of the limitations of this study is that a formal quality assessment of the included studies was not conducted.

Data analysis

A narrative synthesis approach was used to analyse the extracted data from the included studies. Key findings and themes were identified. The findings were organised and presented clearly and systematically to address the research questions and objectives of the review work.

RESULTS

Global trends in TB incidence and prevalence

The global trends in TB incidence and prevalence reflect the historical and current patterns of TB transmission, diagnosis, treatment, and prevention in different regions and populations. TB incidence is the number of new and relapse cases of TB per 100,000 population per year, while TB prevalence is the number of people with TB disease per 100,000 population at a given point in time (Lönnroth

et al., 2009).

According to the World Health Organisation (WHO), the global TB incidence rate has declined by an average of 1.6% per year since 2000, from 173 cases per 100,000 population in 2000 to 127 cases per 100,000 population in 2020 (Wright *et al.*, 2012).

The trends in TB incidence and prevalence are influenced by various determinants that affect the risk of exposure to TB infection, the progression from infection to disease, access to diagnosis and treatment services, and the quality and outcomes of care. Some of these determinants are biological (such as age, sex, and genetic susceptibility), some are behavioral (such as smoking, alcohol use, and treatment adherence), some are environmental (such as air pollution, and indoor crowding), some are social and economic (such as poverty, malnutrition, education), some are health system-related (such as coverage of essential services, availability of drugs and diagnostics), some are epidemiological (such as HIV co-infection, drug resistance) and some are political (such as commitment, funding, governance) (Murray *et al.*, 2001).

Current state of TB incidence

Regional variations

The current state of TB incidence rates is based on data from the [Global Tuberculosis Report 2021] by the World Health Organisation (Bagcchi, 2023) (Table 1).

High-burden countries

High-burden countries are those that have the highest number of new cases or the highest incidence rate of tuberculosis (TB) in the world. These countries are identified by the World Health Organization (WHO) to provide a focus for global action on TB, HIV-associated TB, and drug-resistant TB in the countries where progress is most needed to achieve the targets set in WHO's End TB Strategy, the political declaration of the United Nations (UN) high-level meeting on TB held in 2018 and the UN Sustainable Development Goals (SDGs) (Rahevar *et al.*, 2018).

The WHO releases updated global lists of high-burden countries for TB, HIV-associated TB, and multidrug/rifampicin-resistant TB (MDR/RR-TB) every five years, based on the latest estimates of the incidence of TB, HIV-associated TB, and rifampicin-resistant TB that are published in WHO's Global Tuberculosis Report (Rekart *et al.*, 2023).

Table 2 shows the high-burden countries for TB, HIV-associated TB, and MDR/RR-TB for 2021-2025, according to the WHO (2021a).

Table 1. Global Tuberculosis Report 2021

S/N	Region/group	TB incidence rate
1	World	130.0
2	Africa	237.0
3	Americas	25.0
4	Eastern Mediterranean	63.0
5	Europe	23.0
6	South-East Asia	180.0
7	Western Pacific	78.0

Table 2. High-burden countries for TB, HIV-associated TB, and MDR/RR-TB for 2021-2025

High-burden countries for TB	High-burden countries for HIV-associated TB	High-burden countries for MDR/RR-TB
Afghanistan	Angola	Bangladesh
Bangladesh	Botswana	Belarus
Brazil	Cameroon	China
Cambodia	Central African Republic	Democratic Republic of Congo
China	Congo	Ethiopia
Democratic Republic of Congo	Eswatini	India
Ethiopia	Gabon	Indonesia
India	Guinea	Kazakhstan
Indonesia	Kenya	Kyrgyzstan
Kenya	Lesotho	Moldova
Mozambique	Liberia	Mongolia
Myanmar	Malawi	Myanmar
Nigeria	Mozambique	Nepal
Pakistan	Namibia	Pakistan
Philippines	Nigeria	Peru
Russian Federation	Papua New Guinea	Philippines
South Africa	Rwanda	Russian Federation
Thailand	Sierra Leone	South Africa
United Republic of Tanzania	South Africa	Ukraine
Uganda	Uganda	Uzbekistan
Viet Nam	Zambia	Viet Nam
Zambia	Zimbabwe	Zambia
Zimbabwe	Zimbabwe	

Vulnerable populations

Vulnerable populations are those who are at increased risk of developing tuberculosis (TB) due to biological, behavioural, environmental, social, economic, or health system factors. These factors can affect the exposure to TB infection, the progression from infection to disease, the access to diagnosis and treatment services, and the quality and outcomes of care. Vulnerable populations may also face stigma, discrimination, and human rights violations that hinder their ability to seek and receive TB care. Examples of vulnerable populations in global trends of TB incidence and prevalence are:

People living with HIV (PLHIV): PLHIV are about 20 times more likely to develop TB than people without HIV,

due to their weakened immune system (Temesgen *et al.*, 2019). In 2020, an estimated 1.2 million (12%) of the ten million people who developed TB were PLHIV, and 208,000 (15%) of the 1.4 million people who died from TB were PLHIV (Chakaya *et al.*, 2021).

People with diabetes: People with diabetes have a three times higher risk of developing TB than people without diabetes, due to their impaired immune response (Dooley *et al.*, 2009). Diabetes is also associated with worse TB treatment outcomes, such as delayed sputum conversion, treatment failure, and death (Viswanathan *et al.*, 2014).

Children: Children are more susceptible to TB infection and disease than adults, especially those under five years of age, due to their immature immune systems. Children

also have a higher risk of developing severe forms of TB, such as military TB and TB meningitis, which can cause long-term disability or death. The WHO recommends that children who are in contact with people with TB should receive preventive treatment for latent TB infection, that children with suspected or confirmed TB should receive child-friendly formulations of anti-TB drugs, and that children in high TB burden settings should receive Bacille Calmette-Guérin (BCG) vaccination at birth (Marais *et al.*, 2004).

Types of drug resistance in tuberculosis

Multidrug-resistant tuberculosis (MDR-TB)

MDR-TB, resistant to key drugs in standard TB treatment, arises from factors like inadequate treatment and person-to-person transmission, posing a significant public health threat globally. Treating MDR-TB is more complex, requiring longer, costlier, and potentially more toxic medication regimens. Its economic burden extends to individuals, families, and healthcare systems worldwide. To address this challenge, robust TB control programs, early detection of drug resistance, and research into new, more effective treatments are essential, alongside contact tracing and infection control measures to prevent further spread (WHO, 2021b; CDC, 2021).

Extensively drug-resistant TB (XDR-TB)

XDR-TB, resistant to first-line drugs and at least one fluoroquinolone and injectable second-line drugs, poses immense challenges to treatment due to its resistance profile. Its prevalence varies globally, with high-burden countries at greater risk, often hindered by limited healthcare infrastructure. Accurate and timely diagnosis is a hurdle, as conventional tests may miss drug resistance, while access to advanced molecular diagnostics remains limited. Treating XDR-TB requires prolonged, often costly courses of antibiotics with serious side effects, exacerbating public health risks and underscoring the urgent need for improved control measures and international efforts such as the "End TB Strategy." (Chakaya *et al.*, 2020, 2019; Sotgiu *et al.*, 2021).

Mechanisms of drug resistance

Treatment non-adherence: Incomplete or erratic adherence to prescribed TB treatment regimens is a major contributor to drug resistance. TB treatment requires a combination of multiple antibiotics taken for an extended period. Patients who do not adhere to their treatment schedule may not fully eliminate the bacteria, creating conditions for drug resistance to develop. This can lead to

the emergence of drug-resistant strains and the need for more prolonged and costly treatment (WHO, 2019).

Inadequate healthcare systems: Inadequate healthcare systems, characterized by limited access to quality care, diagnostic delays, and suboptimal monitoring, contribute significantly to TB drug resistance. Due to weak healthcare infrastructure, patients may not receive timely diagnoses or appropriate treatment. This delay allows drug-resistant strains to proliferate and spread within communities (WHO, 2019).

Genetic mutations: Genetic mutations in the *Mycobacterium tuberculosis* bacterium (Mtb) are a fundamental driver of drug resistance. These mutations can alter the target sites of anti-TB drugs, rendering them ineffective. The emergence of multidrug-resistant tuberculosis (MDR-TB) and extensively drug-resistant tuberculosis (XDR-TB) is often associated with these genetic changes. For example, mutations in the *rpoB* gene confer resistance to rifampicin, a crucial first-line drug in TB treatment (Gygli *et al.*, 2017).

Treatment approach

Conventional tuberculosis treatment

Conventional TB treatment involves a standardized regimen of antibiotics that has been established through decades of clinical research and practice. The goal of TB treatment is to cure the infection, prevent the development of drug resistance, and reduce the risk of transmission to others. Key components of conventional TB treatment:

Four-drug combination therapy: The cornerstone of TB treatment is a four-drug combination regimen that typically includes the following antibiotics: Isoniazid (INH), Rifampicin (RIF), Pyrazinamide (PZA), Ethambutol (EMB).

Treatment phases: TB treatment is divided into two main phases:

(1). Intensive phase: In the first 2 months, patients take all four drugs to rapidly kill the active bacteria and reduce their contagiousness.

(2). Continuation phase: In the next 4-6 months, patients continue with a combination of INH and RIF to eliminate any remaining bacteria and prevent relapse.

Directly observed therapy (DOT): To ensure treatment adherence and reduce the risk of drug resistance, healthcare providers often administer TB medications under direct observation. Patients may take their medications at a healthcare facility or have a healthcare worker visit them daily to supervise medication intake.

Monitoring and evaluation: Patients are regularly moni-

tored for signs of improvement, adverse effects, and compliance with treatment. Chest X-rays and sputum tests are used to assess treatment progress.

Drug susceptibility testing (DST): In cases of drug-resistant TB or suspected resistance, DST is performed to determine which antibiotics will be effective against the specific strain of *Mycobacterium tuberculosis*.

Duration of treatment: The total duration of TB treatment typically ranges from 6 to 9 months, depending on factors such as drug susceptibility, response to treatment, and the site of infection.

Adverse effects: TB medications can have side effects, such as liver toxicity, gastrointestinal upset, and visual disturbances. Healthcare providers closely monitor patients for these adverse effects and adjust treatment as needed (WHO, 2020; CDC, 2016; Zumla *et al.*, 2013).

Challenges in MDR-TB and XDR-TB treatment

Limited treatment options: MDR-TB and XDR-TB are resistant to the most effective first-line TB drugs, such as isoniazid and rifampicin. This necessitates the use of second-line drugs, which are often less effective, more toxic, and require longer treatment durations.

Complex treatment regimens: Treating MDR-TB and XDR-TB often involves long and complex regimens lasting up to two years or more. Patients must adhere meticulously to these regimens, which can be challenging and lead to treatment interruptions.

Drug toxicity: Second-line drugs used to treat MDR-TB and XDR-TB can have severe side effects, including hearing loss, kidney damage, and psychiatric disorders. Managing these side effects adds to the complexity of treatment.

High treatment costs: The drugs used to treat MDR-TB and XDR-TB are expensive, and the lengthy treatment durations result in high healthcare costs. This poses a significant financial burden on healthcare systems and patients.

Limited access to diagnostic tools: Diagnosing MDR-TB and XDR-TB can be challenging, particularly in resource-limited settings, due to the limited availability of advanced diagnostic tools like GeneXpert and drug susceptibility testing.

Inadequate healthcare infrastructure: Many regions with high TB burdens lack the necessary healthcare infrastructure, including trained healthcare workers, laboratories, and access to medications, making it difficult

to provide adequate care for MDR-TB and XDR-TB patients.

Stigma and social factors: TB, especially drug-resistant forms, is associated with stigma and discrimination. This can lead to delayed diagnosis, treatment refusal, and poor treatment adherence among affected individuals.

High mortality rates: MDR-TB and XDR-TB have significantly higher mortality rates compared to drug-susceptible TB due to the challenges in diagnosis and treatment, resulting in many deaths (WHO, 2020; Falzon *et al.*, 2018).

Novel treatment strategies for tuberculosis

Several novel approaches have been explored to improve TB treatment, with a focus on shorter, more effective regimens and targeted therapies. Some key novel treatment strategies include:

Host-directed therapy (HDT): HDT aims to modulate the host's immune response to enhance the effectiveness of existing TB drugs. Agents like vitamin D and immune-modulating drugs have been investigated for their potential to augment the body's defense mechanisms against TB (Zumla *et al.*, 2015).

Phage therapy: Bacteriophages are viruses that infect and kill bacteria, including *Mycobacterium tuberculosis*. Phage therapy involves using specific phages to target TB bacteria (Dedrick *et al.*, 2019).

New drug combinations: Developing novel combinations of antibiotics with different mechanisms of action can help shorten treatment duration and combat drug resistance. Regimens like Bedaquiline, Pretomanid, and Linezolid (BPaL) have shown promise (Conradie *et al.*, 2020).

Immunotherapies: Immunotherapeutic approaches, such as therapeutic vaccines and monoclonal antibodies, are being explored to enhance the immune response against TB (Pachouri *et al.*, 2019).

Nanoparticle-based drug delivery: Nanoparticle carriers can improve drug solubility, bioavailability, and target delivery to TB-infected cells, potentially reducing treatment duration and side effects (Pachouri *et al.*, 2019).

Machine learning and AI: Artificial intelligence and machine learning are being used to analyze TB data, predict drug resistance, and optimize treatment regimens for individual patients (Hansun *et al.*, 2025).

Personalized medicine: Tailoring TB treatment based on

an individual's genetic and microbiome profiles holds promise for more effective and patient-specific therapy (van der Werf and de Reus, 2023).

DISCUSSION

Social and cultural factors

The stigma associated with tuberculosis (TB) persists in institutions, communities, and among individuals. It is further compounded by cultural convictions, financial constraints, and misunderstandings. TB is frequently linked to issues like homelessness, poverty, and HIV, which fuels prejudice and social exclusion. Recent studies have shown that people experiencing homelessness have a significantly higher risk of developing TB (pooled odds ratio: 4.53, 95% CI: 2.53-8.11) (Lewinsohn *et al.*, 2017), while poverty is a significant predictor of TB incidence and mortality in low- and middle-income countries (Lienhardt *et al.*, 2019). Additionally, TB remains a leading cause of death among people living with HIV, with approximately 8.7 million people worldwide living with both HIV and TB in 2020 (WHO, 2022). These factors increase transmission and disease progression through overcrowding and poor living conditions, malnutrition and compromised immune systems, delayed diagnosis and treatment, and increased vulnerability to infection (Lewinsohn *et al.*, 2017; Lienhardt *et al.*, 2019; WHO, 2022). Delays in seeking medical attention due to fear of discrimination raise the risk of serious illness and transmission. Stigma-driven misconceptions about therapy have the potential to deteriorate adherence and develop medication resistance. To effectively address TB stigma, comprehensive efforts and education must be made, with an emphasis on the need for informed communities and nuanced methods to regulate attitudes surrounding the disease (Bresenham *et al.*, 2020; Courtwright and Turner, 2010; Duko *et al.*, 2019).

Healthcare system challenge

Disparities in access to DR-TB care in Nigeria were shown to be dependent on sociodemographic variables such as age, gender, occupation, education level, and religion. These findings called for initiatives to guarantee equitable access. According to the study, there is a "medical poverty trap" that is made worse by rising healthcare costs and falling earnings. This has led to measures to provide more financial aid and TB treatment options. Kerala integrated testing with COVID-19 screening to maintain services during the epidemic and enhanced TB notification through causative analysis and customised guidelines. HIV/AIDS patients in China had a greater incidence of tuberculosis (TB), and risk factors for the disease included smoking and a low CD4+ T cell count. However, a history of BCG

immunisation appeared to be protective. The prognoses for COVID-19/TB co-infection were poorer, with higher fatality rate indicators. This suggests that routine TB testing is crucial for COVID-19 cases, especially in high TB-burden countries (Oga-Omenka *et al.*, 2020; Khobragade *et al.*, 2022; Qi *et al.*, 2023; Song *et al.*, 2021).

Strategies for mitigating tuberculosis and drug resistance

Prevention measures

Vaccination programs: tuberculosis vaccine programs have been a long-standing program for decades and have been pivotal in the fight against TB, especially in countries with high incidence. The most widely used vaccine preventive measure is the use of Bacillus Calmette- Guerin (BCG), which was developed in the early 20th century in 1921 and is part of the routine childhood vaccine for preventable childhood diseases in Nigeria under the Expanded Programme on Immunization (EPI) administered at birth yet TB is still prevalent in Nigeria (Orogade *et al.*, 2013). BCG vaccine provides partial protection against severe forms of TB in infants and young adults but fails to stop transmission of pulmonary TB in adults.

Improved diagnosis and surveillance

Advancements in diagnostic technologies: Advancements in diagnostic technologies have brought about a significant transformation in the field of TB management. Traditional diagnostic methods, like sputum smear microscopy, often had limitations regarding accuracy and speed. Modern diagnostic tools, such as GeneXpert and molecular-based tests, have overcome these limitations. GeneXpert, for example, is a cutting-edge molecular diagnostic platform that can detect TB bacteria and drug resistance markers accurately within hours, as opposed to days or weeks required by conventional methods. These molecular tests work by identifying the genetic material of the TB bacteria, allowing for precise and sensitive detection. This accuracy is crucial in cases where TB coexists with other respiratory conditions, ensuring a precise diagnosis (Singh and Chibale, 2021).

One of the most significant advantages of these advanced diagnostic tools is their ability to detect TB and drug resistance simultaneously. This is crucial in highly prevalent regions where drug-resistant TB strains are prevalent. Molecular-based tests can identify specific genetic mutations associated with drug resistance, such as to isoniazid or rifampicin. This information helps healthcare providers prescribe appropriate treatments,

avoiding ineffective drugs and reducing the risk of further drug resistance development.

Strengthening surveillance systems: Surveillance systems for TB track the prevalence, incidence, and drug resistance patterns. Strengthening these systems involves improving data collection, analysis, and reporting and is pertinent to identify hotspots, monitor trends, and allocate resources effectively to combat TB and avoid MDR infections (Lönnroth *et al.*, 2015). Surveillance systems are the cornerstone of understanding the disease's dynamics within a population and are metrics for assessing burden. Monitoring drug resistance patterns is equally critical and helps to identify which TB drugs are becoming less effective due to resistance, allowing for adjustments in treatment protocols. The data collected should be comprehensive, accurate, and timely. This often requires training healthcare workers and implementing digital systems for data entry and transmission to ensure the availability of real-time information (WHO, 2014a).

Treatment and drug discovery

Research on new drugs and regimens: TB treatment has relied on antibiotics, e.g. isoniazid and rifampicin, taken over a long duration; however, with the emergence of drug-resistant strains, there has been a need for new drug discovery. In December 2022, the World Health Organisation released "The consolidated guidelines on TB" with newer drugs like Bedaquiline, pretomanid, linezolid, and Delamanid developed to treat drug-resistant TB; understanding antibiotic resistance is not straightforward, as resistance can appear because of a persistent phenotype, which is displayed by drug-tolerant populations of *Mtb* known as persisters. Research is also ongoing to develop shorter and patient-friendly drugs that reduce intake from months to weeks, like in the case of Tuberculosis Preventive therapy for HIV management research on new drugs and regimens (WHO, 2014b).

Patient-centred care approaches: TB treatment goes beyond just administering drugs; patient-centred care recognises the importance of addressing the holistic needs of individuals affected by TB. DOTS (Directly Observed Treatment, Short-Course) is a great example of a patient-centred approach where healthcare workers or trained community members directly observe patients taking their TB medications. This ensures treatment adherence and fosters a supportive patient-provider relationship. Patients often face stigma and social challenges related to TB. Patient-centred care involves providing psychosocial support, counselling, and education to help individuals cope with the emotional and social aspects of TB. Some patients may have comorbidities or unique circumstances that require personalised treatment plans. Patient-centred

care involves tailoring treatment to meet individual needs. Engaging communities in TB care and prevention efforts is vital (Pang *et al.*, 2017). It empowers patients and their families to be active participants in their treatment and helps reduce the stigma associated with the disease.

CONCLUSION

Global trends in TB incidence and prevalence indicate progress, but significant challenges persist, particularly in addressing regional disparities and vulnerable populations. The COVID-19 pandemic has posed additional hurdles to TB control efforts, highlighting the need for continued investment in healthcare infrastructure and diagnostics. Drug-resistant TB poses substantial challenges, including difficult and expensive treatment, delayed diagnosis, and limited access to effective treatment options. Emerging challenges in TB control include the rise of drug-resistant strains, socioeconomic factors, and the need for improved diagnostic tools and vaccines. To combat TB, global health policy recommendations include strengthening healthcare systems, enhancing laboratory capacity, ensuring universal access to quality TB care, and promoting research and innovation.

Future directions for TB control efforts

To combat the spread of drug-resistant TB, there is a critical need for improved diagnostics, treatment regimens, and novel drugs, as well as targeted therapies and personalised treatment approaches. Future directions in TB control should focus on integrating TB and COVID-19 responses, developing effective TB vaccines, leveraging digital health technologies, and addressing social determinants of TB and health equity. Additionally, strengthening healthcare systems, investing in research and development, promoting community engagement, and reducing stigma are essential for achieving sustained TB control efforts.

CONFLICT OF INTEREST

All authors declared that they have no conflict of interest.

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