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Review Article

A Comprehensive Review of Tuberculosis in India: Incidence, Prevalence, Challenges, and Strategies for Elimination

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ABSTRACT

Especially in countries with lower and middle income levels like India, tuberculosis poses a serious worldwide health concern. Numerous individuals still get the disease every year despite advancements. The spread, causes, Global and national data and difficulties in diagnosing and treating tuberculosis in India are all examined in detail in this review. A major concern is latent tuberculosis infection, which can develop into active tuberculosis, particularly in people with weak immune systems, chronic illnesses like diabetes, or in high-risk environments such as prisons or healthcare settings. Drug resistance in tuberculosis, including multidrug-resistant strains, adds complexity to treatment efforts. Newer technologies, such as the interferon-gamma release assay (IGRA) and molecular diagnostics, hold promise despite the limitations of traditional diagnostic techniques like the tuberculin skin test. Co-infections like HIV and social factors like poverty, nutrient deficiencies, and inadequate healthcare infrastructure are major contributors to the spread of tuberculosis.

INTRODUCTION

Tuberculosis (TB) has been a leading cause of the most life-threatening contagious illness for centuries, and it continues to pose a major health burden. The WHO Global Tuberculosis Report (2024) highlights that tuberculosis continues to heavily affect low- and middle-income regions, where healthcare resources are often scarce and public health infrastructure is weak.[1] India, with its high population and high disease burden, represents one of the epicenters of this global health crisis. In 2023, India accounted for about 25% of all tuberculosis cases globally.[2] Tuberculosis predominantly targets adults during their prime working age, and the disease's economic consequences, both in terms of lost productivity and healthcare costs, are substantial.[3] A key issue in TB control is the phenomenon of latent tuberculosis infection (LTBI), which refers to individuals who carry the TB bacteria but do not show active symptoms of the infection. These people remain vulnerable to progressing to active tuberculosis later, particularly if their immune systems become weakened.[4] LTBI represents a significant public health threat because it acts as a reservoir for future TB cases, with individuals unknowingly transmitting the disease to others. In India, the occurrence is alarmingly elevated, especially in locations lacking adequate medical care and preventive services.[5]

In addition to LTBI, multidrug-resistant TB (MDR-TB) and extensively drug-resistant TB (XDR-TB) have become major obstacles. *Mycobacterium tuberculosis* that is resistant to both isoniazid and rifampicin, the two main first-line TB drugs, causes MDR-TB. Poor treatment adherence, incomplete or incorrect drug regimens, and misuse of antibiotics have exacerbated the rise of drug-resistant strains. This resistance makes TB more difficult

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to treat, leading to longer treatment durations, more severe side effects, and higher costs.[6] People living in poverty face an increased chance of contracting tuberculosis because of issues like poor nutrition, restricted medical care facilities, and living conditions that favor the spread of infectious diseases.[7] In India, where the majority of the population lives in rural areas or urban slums, these conditions are prevalent, making TB transmission even more widespread. TB is also tightly linked with other diseases such as HIV, diabetes, and malnutrition. Having both TB and HIV simultaneously is particularly risky because HIV compromises immunity, making individuals more vulnerable to TB infection. The relationship between diabetes and TB is also becoming increasingly important, as individuals with diabetes are at elevated risk of tuberculosis infection and may experience poorer treatment outcomes.[8]

In response to these challenges, the Indian government, along with international organizations like the WHO, has developed a range of strategies to control and eliminate TB. The National Strategic Plan for Tuberculosis Elimination (2017-2025) in India strives to eradicate TB by 2025, emphasizing early detection, rapid treatment, and enhanced preventive measures. The WHO's End TB Strategy, which includes goals for TB prevention, diagnosis, and treatment, provides a global framework to guide these efforts.[9] However, achieving these ambitious targets requires overcoming significant barriers, such as the high prevalence of LTBI, the rise of drug-resistant strains, inadequate healthcare infrastructure, and the social determinants that fuel TB transmission.

This review paper aims to provide an in-depth examination of the current state of TB in India and globally, exploring the prevalence of TB, the challenges posed by LTBI, MDR-TB, and co-infections, and the efforts underway to eliminate TB. By understanding the multifaceted nature of TB and the complex interactions between biological, social, and economic factors, this work seeks to support the current global discussion on TB control and prevention.

Epidemiology Of Tuberculosis

Global and National Statistics

Tuberculosis continues to be a threatening worldwide health challenge, with the World Health Organization's (WHO) Global Tuberculosis Report 2024 providing a comprehensive overview of 2023 data. An estimated 10.8 million people globally are infected with tuberculosis (TB), resulting in an incidence rate of 134 cases per 100,000 population.[10] Outrageously, 1.25 million people lost their lives due to TB, out of which 161,000 were HIV positive individuals. TB, thus, remains the leading infectious disease killer in the world.[1,10] According to the report, adult men still carry the burden above any other demographic group, where men account for 6.0 million (55%) of the incident cases, women 3.6 million (33%), and children and young adolescents (0–14 years) 1.3 million (12%) cases (Fig. 1).[10,11]

India still carries the largest burden of TB in the world. In 2023, India projected 2.8 million (28 lakh) new TB cases, which is around 26% of the total estimated figure (Fig. 2).[12] The TB incidence rate in the country also improved. It is now 195 per lakh population, which is a 17.7% improvement since 2015.[13] There was also a record high notification of TB cases in the country as the NTEP reported 2.55 million (25.5 lakh) cases.[14] Furthermore, India is estimated to have 323,000 (3.23 lakh) TB deaths in 2023, alongside a drop in the death rate from 28 per lakh in 2015 to 22 per lakh population in 2023, which is a 21.4% reduction from 2015 (Fig. 3).[12, 13] Adult males in India are disproportionately affected by TB, consistent with global trends, though 2023 disaggregated data is in national reports.[14]

Age, Gender, and Geographical Variations

The burden of TB in India is not uniform across all demographics. There are significant variations in TB prevalence based on factors such as age, gender, and

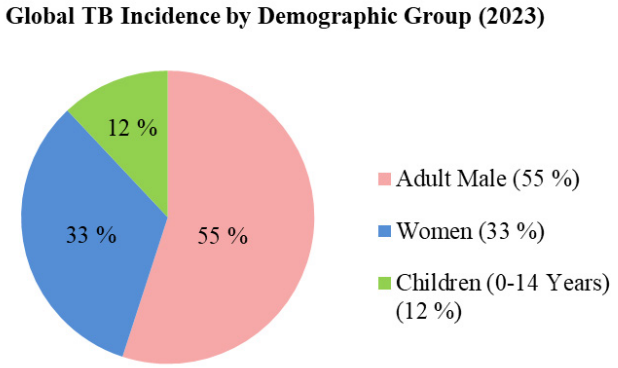

Fig. 1: Global TB incidence by demographic group

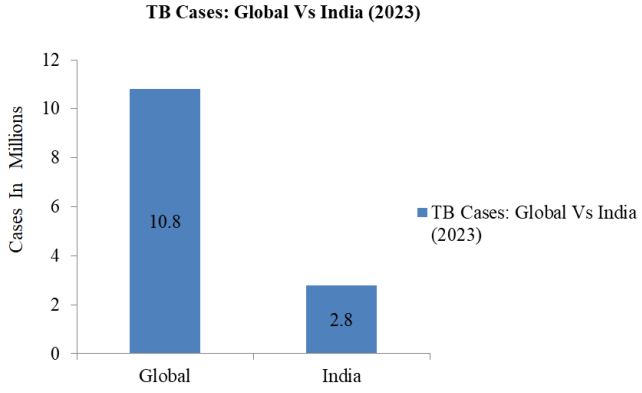

Fig. 2: TB Cases: Global Vs India (2023)

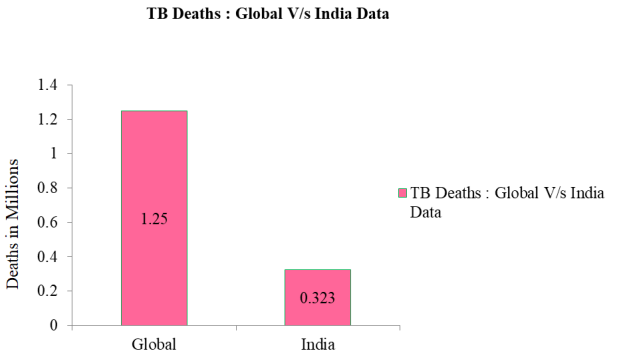

Fig. 3: TB deaths: Global V/s India Data

geography. For instance, the incidence of TB is notably higher among adults, with individuals between the ages of 15 and 54 accounting for the majority of new cases.[15] The disease tends to affect more men than women, with men accounting for approximately 60% of the cases in India, a trend also observed globally (Fig. 4). This discrepancy is partially attributed to lifestyle factors such as tobacco use, alcohol consumption, and work-related exposures, which are more common among men.[4]

Different regions have distinct features that impact tuberculosis (TB) spread within India. Harsh urban slum living conditions foster TB outbreaks due to their overcrowded population and inadequate sanitation. The rural population suffers from high rates of TB due to late diagnosis and limited access to healthcare services. Isolated, underserved tribal communities are left vulnerable to TB due to multi-dimensional malnutrition compounded with cultural gaps.[6, 8] The urban-rural divide in India exacerbates disparities relating to TB. Overcrowding results in increased transmission of TB in urban cities, while the rural population faces late diagnosis and weak treatment options from the inadequate healthcare system.[4]

Vulnerable Populations

In India, Tuberculosis (TB) has become a public health challenge that continues to disproportionately impact marginalized groups. Urban dwellers face the brunt of the TB crisis because of high transmission rates due to increased population density, poor air circulation, as well as less healthcare access.[8] Isolated tribes also experience elevated TB risk due to cultural barriers, inadequate medical services, and malnutrition.[6] Prisoners are another vulnerable segment, with TB rates far exceeding the general population, due to overcrowded housing and substandard healthcare.[17] Additionally, older individuals suffering from diabetes, people living with HIV, and malnourished people also fall under this heightened risk. This puts India's TB burden, accounting for 27% of global cases, at even greater risk, exposing systemic oversights.[9,15] Malnourished individuals, as well as those with HIV and diabetes, are especially at heightened risk. These cases sustain TB-positive conditions that further enable the spread of infection. These gaps can be bridged through geopolitical assistance for recovering regions. Flexible socio-economic strategies catering to support vulnerable groups are what these regions need.

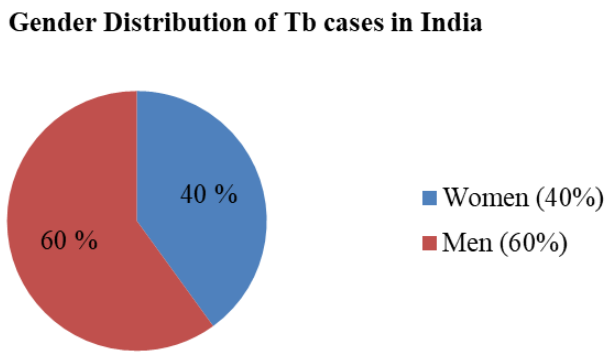

Fig. 4: Gender distribution of TB cases in India

Factors Contributing to the High Burden of Tuberculosis In India

Socio-economic factors

Tuberculosis breeds where poverty lives. In India's congested slums and its remote villages, families cram into ill-ventilated homes, and conditions are ripe for TB to flourish.[16] Most of them do not have the money to pay doctors or have hours-long travel to reach some clinic facilities, at least at such a distance, coughing can go unattended by patients until the damage is done. It gets worse for women and other vulnerable groups with stigma and discrimination erecting invisible walls to health care. So, the little treatment that comes may just be too late. This is not a medical issue. It's a battle against overcrowded houses, empty stomachs, and broken systems that allow TB to win.

Co-morbid Conditions

TB does not come alone. For most Indians, it comes with several other silent epidemics, arriving as a lethal combination with diabetes; while the former triples the risk by compromising defensive mechanisms of the body, the latter compromises blood sugar control in individuals who suffer from both conditions, creating a "vicious health cycle".[8] Even more fatal is when TB meets HIV, found in 10 to 15% of HIV patients.[16] Stigma and treatment complexity mean that care for such co-morbidities will often be sought too late. In India's already overstretched healthcare system, such intersecting diseases form veritable perfect storms wherein one disease process acts to fuel another, crying out for integrated solutions at the interface of these complex health relationships.

Multidrug-resistant tuberculosis (MDR-TB)

India faces a growing nightmare - tuberculosis that defies

standard medicines. Multidrug-resistant TB (MDR-TB), resistant to our strongest drugs, now affects about 130,000 Indians yearly.[18,19] This disease is born due to incomplete treatments, improper antibiotic use, and our overburdened healthcare system. MDR-TB treatment means putting up with toxic, expensive treatments for two years, harsh side effects, and lower success rates. The perpetual war against such conditions must involve better diagnostics, better drugs, and most of all, ensuring that every patient finishes his or her full course of treatment; for if tuberculosis treatment fails, the whole world pays the price. As reported in 2023 by the WHO, in 2022, there were 410,000 new cases of MDR-TB globally, with a 63% treatment success rate. India reported 63,000 cases, which represents 27% of the global total. The Nikshay portal indicates that although there is improvement in TB's antecedent gaps in care pathways remain.

Diagnosing MDR-TB, an isoniazid and rifampicin-resistant form of tuberculosis, involves culture and molecular methods. Drug susceptibility testing can be performed with solid media like Lowenstein-Jensen (LJ) and liquid systems such as MGIT 960. Rapid detection of resistance can be performed with molecular tests like GeneXpert MTB/RIF and line probe assays (LPAs).[2,14] Treatment requires an 18 to 24-month regimen of second-line drugs including bedaquiline, linezolid, and fluoroquinolones. Selective patients may be placed on the BPaL regimen (bedaquiline, pretomanid, linezolid), which reduces the duration to 6–9 months. Following treatment, there is a need for monitoring to check for relapse and manage hepatotoxicity and neuropathy side effects.

Current Diagnostic and Screening Methods for Tuberculosis in India

Accurate and prompt diagnosis of tuberculosis is crucial for controlling its spread, particularly in a country like India, which bears a major segment of the global tuberculosis impact. India uses a combination of traditional and modern diagnostic tools to detect TB, each with its own set of advantages and limitations.

Traditional Diagnostic Approaches

For decades, India's TB detection relied on three workhorses: chest X-rays, sputum tests, and skin tests. While still used across rural clinics, these methods show their age. X-rays reveal lung damage but can't distinguish TB from other diseases. Sputum microscopy - the longtime gold standard - misses 50% of cases and fails with drug-resistant strains. The tuberculin skin test plays guessing games, reacting to BCG vaccines and failing those with weakened immunity. [22, 27]

These traditional tools served their purpose in simpler times, but today's TB demands sharper weapons. Each undetected case becomes a transmission risk, each misdiagnosis a potential tragedy. While they remain vital in resource-limited settings, India's TB program now increasingly turns to molecular tests and advanced imaging, because when lives hang in the balance, we can't afford yesterday's diagnostics for today's TB crisis.

Modern Diagnostic Tools

The fight against TB in India is being upgraded to the 21st century. It is no longer fully reliant on fuzzy X-rays and hit-or-miss sputum tests; diagnostic tools today work like molecular detectives, spotting TB with unprecedented accuracy. The QuantiFERON blood test is a quantum leap. It cannot be fooled by BCG vaccines, like the old skin tests, and pinpoints latent infections before they become dangerous. But the real game-changer is GeneXpert. This tiny box performs magic by detecting TB bacteria and drug resistance within hours instead of weeks.[20] In simple terms, for a country grappling with MDR-TB, that is to have the right treatment started before the disease spreads. These technologies are expensive and require trained personnel, but consider the alternative: every missed diagnosis entailing a fresh round of infection; every delayed result meaning weeks of contagious uncertainty. This is essentially what India's TB program is now banking on: these instruments of precision. Multiple diagnostic techniques exist for identifying TB at an early stage (Table 1).

Screening in Special Populations

Screening plays a crucial role in helping to identify TB early, particularly among higher-risk groups in India. Populations at high-risk include individuals living with HIV, close contacts of patients diagnosed with TB, healthcare workers, and diabetes patients. Details are given in Table 2. These populations are especially high-risk because they are at both an increased risk of infection and an increased risk of progression from latent TB to active TB.

Latent Tuberculosis Infection (LTBI) and Preventive Strategies in India

Latent tuberculosis infection (LTBI) means people have *Mycobacterium tuberculosis* in their bodies but don't show symptoms or spread the disease. These individuals could develop active TB if their immune system weakens due to HIV or diabetes.[25] LTBI poses a major health issue in countries with high TB rates, like India. Experts think that one-third of people worldwide might have LTBI, creating a hidden pool of potential future active TB cases.[26] In India, LTBI prevalence changes based on region and risk group. Healthcare workers, close contacts of active TB patients, and people with other health issues show higher rates. The chance of LTBI turning into active TB makes it crucial to detect and treat. The National Strategic Plan to Eliminate TB (2017–2025) focuses on managing LTBI as a key approach through preventive drugs like isoniazid or rifampicin.[2] Even with these plans, putting them into action has its problems. Many LTBI cases go unnoticed because there are no symptoms and not enough screening

Table 1: Diagnostic tools for diagnosis of TB at the early stage

Method	*Description*	*Application*	*Reference*
Symptom screening	Identifies individuals with symptoms like persistent cough, fever, weight loss, and night sweats	Used in community settings, OPDs, and high-risk groups	[12, 21, 23]
Chest X-ray (CXR)	Imaging to detect lung abnormalities suggestive of TB	Widely used for screening, especially in contact tracing and among high-risk groups	[2, 9]
Sputum smear microscopy	Examines sputum samples under a microscope for acid-fast bacilli (AFB)	Basic, cost-effective method used in primary health centers	[22]
CBNAAT / GeneXpert	Molecular test that detects TB and rifampicin resistance within 2 hours	Rapid, accurate diagnosis of pulmonary and extrapulmonary TB; especially useful in high-risk patients	[2, 20]
TrueNat	Indigenous molecular diagnostic test developed in India	Point-of-care use in rural areas: scalable and portable	[2, 20]
Line probe assay (LPA)	Detects drug resistance to first- and second-line TB drugs	Used at intermediate reference labs for DST (drug susceptibility testing)	[22]
Tuberculin skin Test (TST)	Detects delayed hypersensitivity to tuberculin antigen	Used for diagnosing latent TB, especially in children and immunocompromised individuals	[21, 23]
Interferon Gamma Release Assays (IGRA)	Blood test for LTBI detection	Preferred in immunocompromised individuals and BCG-vaccinated populations	[9, 23]

Table 2: Screening of Tb in special population

High-risk group	*Rationale for screening*	*Screening importance*	*Reference*
HIV Co-infected Patients	Compromised immunity increases susceptibility to TB; TB is the leading cause of death in HIV-positive individuals.	Routine TB screening helps reduce mortality and control the spread of both TB and HIV.	[24]
Diabetics	Diabetes weakens immunity, increasing the risk of TB; more severe forms and poorer outcomes in co-morbid cases.	Early TB detection in diabetics leads to timely treatment and improved outcomes, essential due to delayed diagnosis and increased severity.	[24]
Healthcare Workers	High exposure to TB patients increases infection risk.	Regular screening helps prevent nosocomial TB transmission and ensures the safety of both healthcare providers and patients.	[24]
Individuals with LTBI	LTBI can progress to active TB, especially in immunocompromised persons.	Screening and treating LTBI in high-risk groups (HIV, diabetics, healthcare workers) prevents future active TB cases, reducing overall TB burden.	[23]

tools. Preventive treatment often needs months of taking medicine, which makes it hard for people to stick to it. In addition, limited medical services in remote regions and a lack of awareness on the part of either patients or providers, both of which are indicators of poor intervention effectiveness. For India to be able to eliminate TB by 2025, it will need to undertake LTBI screenings, improve health care access, and educate the general public and health care providers on the importance of preventive treatment.

Role of BCG Vaccine

The Bacille Calmette-Guérin (BCG) vaccine, introduced in the 1920s, remains crucial to the fight against tuberculosis (TB) disease, particularly in high-burden TB countries like India. The BCG vaccine provides a degree of protection useful for children in early childhood against the more critical types of TB disease, e.g., TB meningitis and miliary TB, but it has limited effectiveness against pulmonary TB in adults. Regardless of the limited protection, the BCG vaccine continues to be given as part of a national immunization program.[27] When processing latent TB infection (LTBI), the BCG vaccine does provide some protection in that it reduces the possibility of active TB disease, particularly for children exposed to *Mycobacterium tuberculosis*. However, even with the BCG vaccine, TB disease cannot be controlled in adults (let alone eradicated). Consequently, in addition to BCG vaccination, each of the following strategies could be used: preventive treatment (therapy) for LTBI and improved diagnosis would help to improve TB disease control and

ultimately achieve TB disease eradication. [28, 32]

Treatment of Tuberculosis in India: Challenges and Future Directions

Tuberculosis (TB) treatment in India is governed by the National Tuberculosis Elimination Programme (NTEP), with the aim of eliminating TB by 2025. The NTEP is an Indian government program that adheres to the World Health Organization (WHO) guidelines and provides free, quality-assured, standardized treatment utilizing the public and private sectors.[2, 9] For patients suffering from drug-sensitive TB, the standard treatment regimen is a total of six months with an intensive phase consisting of isoniazid, rifampicin, pyrazinamide, and ethambutol administered over 2 months, then continued with a maintenance phase of isoniazid and rifampicin for 4 months.[2] For drug-resistant TB (DR-TB), the required treatment regimens will be of significantly longer duration. The second-line treatment for multidrug-resistant TB (MDR-TB) is based on second-line drugs including bedaquiline, linezolid, delamanid, levofloxacin and clofazimine. India has implemented both conventional longer treatment regimens lasting 18 to 24 months, and shorter 9 to 11-month regimens using appropriate cases.[28,31] Adherence support is through the directly observed treatment, short-course (DOTS) strategy, including monitoring through digital means, Nikshay-the TB treatment regimen monitoring site, which also tracks outcomes and decisions. Additionally, India also supports its TB patients through the Nikshay Poshan yojana, providing nutritional support of ₹500/month for the duration of treatment.[2]

It is important to engage the private sector in TB control because a substantial amount of TB disease is treated outside of the public health system. Achievements have been made in notifying and treating cases amidst challenges through arrangements like the Private Provider Interface Agency (PPIA) models.[29] Even with progress, there are still barriers such as treatment non-adherence, drug resistance and under-reporting or delay in notifying with regard to TB cases. Continued investments in diagnostics, newer medications and community-based engagement will be required to achieve India's target of eliminating TB by 2025.

Challenges in TB Treatment

India, despite its progress made by implementing the National Tuberculosis Elimination Programme (NTEP) and the DOTS guidelines, still faces significant overall obstacles to providing optimal TB care, particularly for those in rural and marginalized communities. One of the critical obstacles is patient compliance. Treatment for TB, particularly drug-sensitive TB, requires a patient commitment of six months, or up to two years in the case of drug-resistant tuberculosis. As a result, the longer the patient must adhere to treatment, the more likely they are to discontinue during the treatment, which can be exacerbated by geographical isolation, financial hardship, and social pressures. Stigma associated with TB is still, generally, a major obstacle. Even in countries where health care and access to treatment are provided by the government, in many communities, rural communities particularly, TB is still associated with misconceptions and social discrimination that deter individuals from seeking treatment at all, or continuing treatment. This stigma wields significant power over patients' presenting issues, resulting in social isolation for the patients, and perhaps an increase in mental health complaints, which cumulatively influences further treatment adherence. [7, 12, 21]

Although TB treatment is free from the government, there are still costs to patients as they incur downstream costs of direct treatment when they have to pay for transportation, food, and any loss of wages. For low-income families, the financial burden can be discourage, eventually leading to incomplete treatment and increased risk of developing drug resistance.[3] Access to quality health care shows significant variation as well. Comparative to urban settings, rural settings provide fewer facilities with up-to-date equipment and trained personnel, thereby creating delays in diagnosis and inconsistencies with treatment, which makes the TB burden even worse.

India is not able to continue its progress in containing tuberculosis (TB) and the challenges faced are compounded by the stigma, even today, healthcare infrastructure issues, and the COVID-19 pandemic. Stigma remains an important barrier to timely diagnosis and treatment adherence and the doctrine often follows family traditions, especially in rural areas.[18, 25] Limited diagnostic tests, inadequate facilities, and a shortage of trained healthcare personnel augment the already expensive healthcare system of TB care, especially for drug-resistant TB.[3] Additional setbacks have been caused by the COVID-19 pandemic, which has reduced case notifications due to a lack of healthcare access and compounded treatment interruptions can further fuel drug resistance and enhanced transmission.[25] Given the challenges mentioned above, well-publicized and structural change is needed to increase awareness in the community about the needs of TB patients; physical infrastructure, financial and social well-being of patients; and how treatment systems can be integrated across settings and types of care. Solutions to the societal challenges need community engagement, the potential adoption of digital health tools, and continuity of care initiatives as next steps towards meeting TB elimination in India.

Public Health Strategies and Policies

India's targets for tuberculosis (TB) elimination in 2025 are anchored in the National Strategic Plan for Tuberculosis Elimination 2017-2025. The goal here is an emphasis on universal access to prompt diagnosis and

treatment, and prevention.[2] Importantly, active case finding, community participation, managing for drug-resistant TB, and so on underlie targets for TB elimination. Community engagement through sleights like social mobilization led by ASHA workers is vitally important in rural areas where TB patients are often difficult to identify and encouraged to start treatment.[2,29,30] Links with HIV and diabetes programs also improved TB treatment and care outcomes among vulnerable populations.[8] Global partnerships, especially with WHO and the Global Fund, support the TB program in India globally in terms of technical and financial support.[31] Concretely, public-private partnerships have led to improvements in case reporting (informal and formal) and access to care, especially since most TB patients are treated in private care. International research collaborations have led to the introduction of new diagnostics, e.g., GeneXpert, and new drugs, e.g., bedaquiline, that more effectively and efficiently treat and cure drug-resistant TB patients.[20]

Future Directions

Recent advancements in TB research, diagnostics and treatment offer new hope for lowering rates of TB in high-burden countries such as India. Examples include molecular diagnostics like GeneXpert MTB/RIF, which can accurately and rapidly diagnose TB and rifampicin resistance; results are available in ~2 hours *versus* traditional time frames that ranged from weeks to months. Therefore, early treatment will improve chances of successful outcomes. Interferon-gamma release assays (IGRAs), such as QuantiFERON-TB, can detect latent TB infections more reliably than traditional methods such as tuberculin skin tests.[20,32] Efforts to improve treatment outcomes by studying new drugs and shorter treatment regimens for multidrug-resistant TB (MDR-TB) continue.[33] New promising vaccine candidates like MTBVAC and VPM1002 may offer wider protection than the current BCG.[27] Finally, personalized medicine based on genomics and pharmacogenomics aims to offer personalized or tailored treatments for the individual, thus improving treatment efficacy while reducing negative side effects, signaling a drastic change in treatment approaches to TB.[20]

Conclusion

Tuberculosis continues to present a considerable public health issue in India, fueled by poverty, stigma, and inconsistencies in healthcare access. Despite advancements, India continues to have the greatest TB burden in the world, compounded by increasing drug resistance.[18,19] There are promising new tools, including GeneXpert, as well as community-based interventions that have shown success, but require wider implementation.[20,30] To eliminate TB by 2025, we must maintain stronger policy commitment, increase community engagement, and strengthen the healthcare system.[2, 3]

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