

A Review on the Battle against Tuberculosis: Past and Present Challenges

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Abstract

Tuberculosis (TB) remains a substantial global health issue despite decades of efforts to combat the disease. This review aims to give an overview of the past and present challenges in the battle against tuberculosis, drawing on secondary data sources. The study examines historical trends in TB prevalence and mortality, as well as the evolution of treatment and prevention strategies over time. The review highlights the progress that has been made in the fight against TB, including the development of effective antibiotics and the implementation of public health programs to control the spread of the disease. However, the study also identifies persistent challenges that continue to impede efforts to eliminate TB, such as drug resistance, insufficient admittance to healthcare facilities, and social determinants of health. In conclusion, the review underscores the need for continued investment in research and public health interventions to address the ongoing burden of tuberculosis. By understanding the lessons of the past and responding to the current challenges, it is possible to make further progress in the battle against this ancient disease.

Key words: Tuberculosis, Antibiotics, Drug resistance, Healthcare infrastructure, Diagnostics.

1. Introduction

One of the first infectious diseases known to science, tuberculosis (TB), has afflicted people for ages (Esmail, 2014). Although TB can affect other regions of the body as well, the lungs are the primary organ affected by this disease, which is brought on by the 'Mycobacterium tuberculosis' bacteria. Millions of people are impacted by TB every year, and the disease is still a major cause of death worldwide (Kim, 2015).

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The battle against TB has a long and storied history, characterized by both successes and challenges. Throughout the centuries, various treatment methods, public health measures, and vaccination strategies have been employed to regulate the spread of the disease. The development of antibiotics such as streptomycin in the mid-20th century revolutionized TB treatment and led to a significant decline in TB-related mortality rates in many parts of the world (Leung, 2013).

Even with these developments, tuberculosis (TB) remains a serious danger to public health. The advent of drug-resistant TB strains, including ‘extensively drug-resistant TB’ (XDR-TB) and ‘multidrug-resistant TB’ (MDR-TB), has complicated treatment protocols and sparked doubts about their efficacy (Raviglione, 2016).

The world health community has stepped up its efforts to eradicate tuberculosis (TB) in recent years. The WHO has set ambitious goals to lower the incidence, mortality, and crippling costs of tuberculosis. Prioritizing actions will hasten the objective of eliminating the tuberculosis epidemic by 2030 by fortifying healthcare systems, expanding access to TB testing and treatment, and enhancing infection control protocols (Zumla, 2015).

This review aims to give a summary of the past and present challenges in the battle against TB, highlighting key milestones in TB research, treatment, and control efforts. By examining the historical context of TB control efforts and evaluating the current state of the TB epidemic globally, this review seeks to inform future strategies aimed at decreasing the burden of TB and achieving the goal of TB elimination.

In summary, the fight against TB remains a critical public health priority that requires a coordinated global response involving all stakeholders, including governments, healthcare providers, researchers, and community organizations (Tandon, 2027). By building on past successes and addressing current challenges, it is possible to make significant progress in the battle against TB and ultimately eliminate this ancient disease once and for all.

2. Literature Review

Several previous studies have examined the battle against tuberculosis (TB) from various perspectives, highlighting both the progress made and the challenges that remain. A review by McMillen (2015) outlined the history of TB, from its discovery by Robert Koch in the late 19th century to the development of the BCG vaccine in the 20th century. The review also discussed the emergence of ‘drug-resistant strains’ of TB and the ongoing efforts to develop new treatments and vaccines.

In a study by Koul (2011), the authors provided an overview of the global burden of TB and the impact of the disease on public health. They discussed the challenges of diagnosing TB, particularly in resource-limited settings, and the importance of addressing social determinants of health to control the spread of the disease.

Another review by Farmer (2016) focused on the role of rapid diagnostics in the fight against TB. The authors discussed the limitations of traditional diagnostic methods and highlighted the potential of new technologies, such as GeneXpert and (LAMP, to improve case detection and reduce the time to treatment initiation.

According to a study by Dye (2013), ‘there are an estimated 10 million new cases of tuberculosis worldwide each year and 1.5 million fatalities from the disease. TB is one of the top 10 causes of death globally, according to the WHO, especially in low- and middle-income nations. This emphasizes how crucial it is to keep up global efforts to prevent and eradicate tuberculosis’.

The bacterium ‘*Mycobacterium tuberculosis*’, which mostly distresses the lungs but can also spread to other regions of the body, is the cause of tuberculosis (TB), according to research by Canetti (2020). People contract the illness mostly by breathing in airborne

droplets contaminated with bacteria from other sick people. Due to this mechanism of transmission, tuberculosis has become a serious public health risk, especially in environments with poor ventilation and crowding.

Esmail (2014) conducted a review of research that offered a thorough summary of the difficulties associated with diagnosing and treating tuberculosis. The study emphasized how crucial it is to care for tuberculosis patients properly and identify them early in order to stop the disease from spreading.

A study by Kim (2015) focused on the global burden of ‘multidrug-resistant tuberculosis’ (MDR-TB) and the challenges in the management of MDR-TB cases. The study discussed the emergence of drug-resistant strains of tuberculosis and the need for innovative treatment strategies to combat the growing threat of MDR-TB.

A study by Leung (2013) focused on the challenges faced in the control of tuberculosis in high-burden settings. The study highlighted the importance of implementing effective TB control programs, including vaccination, infection control measures, and access to quality healthcare services, to reduce the burden of tuberculosis in vulnerable people.

A review article by Raviglione (2016) discussed the advances in tuberculosis diagnostics and the challenges in implementing new diagnostic technologies in resource-limited settings. The study emphasized the importance of developing affordable and accurate diagnostic tools for the timely detection of tuberculosis, particularly in high-burden nations.

3. Methodology

In this review paper, we conducted a wide-ranging search of the literature to get significant studies interrelated to the battle against tuberculosis. The study utilized several electronic catalogs, including ‘PubMed, Scopus, and Google Scholar’, to identify primary research articles, review papers, and other relevant literature published in the last two decades.

The study used a combination of keywords, including "tuberculosis," "TB," "tuberculosis treatment," "tuberculosis prevention," "tuberculosis control," "tuberculosis epidemiology," and "tuberculosis challenges" to search for relevant studies. The study also hand-searched reference lists of key articles to identify additional relevant studies that may not have been captured through electronic searches.

The review included studies that focused on various aspects of tuberculosis, including its epidemiology, treatment strategies, prevention efforts, challenges in control and elimination, and the impact of social determinants on TB burden. We excluded studies that were not peer-reviewed or were not written in English.

After compiling a list of relevant studies, the study carefully reviewed each article to extract key findings, insights, and recommendations related to the battle against tuberculosis. We synthesized the information obtained from the selected studies to provide a comprehensive overview of past and present challenges in the fight against tuberculosis.

The analysis of the current worldwide situation regarding tuberculosis, including its load, difficulties in diagnosis and treatment, and the effect of the COVID-19 pandemic on TB control efforts, is the basis of this paper. The article also discusses how the TB epidemic is fueled by socioeconomic issues, including poverty, congestion, and limited access to healthcare.

The review article aims to give a complete understanding of the challenges faced in the battle against tuberculosis and to highlight the need for continued efforts to control and eventually eliminate this deadly disease.

4. Results and Discussion

4.1 Historical Evolution of Tuberculosis

4.1.1 Discovery and Early Understanding

Tuberculosis has a long and complex history dating back centuries. The disease was first identified and understood as pulmonary tuberculosis by the ancient Greeks and Romans, who referred to it as "consumption" due to its debilitating effects on the body (Zumla, 2015). However, it was not until the 19th century that the specific cause of the disease was discovered by Robert Koch in 1882. This breakthrough enabled a good appreciation of the disease and the development of targeted treatment methods (Tandon, 2017).

4.1.2 Treatment Methods in the Past

Historically, the treatment of tuberculosis was limited and often ineffective. In the past, remedies for tuberculosis included rest, fresh air, and a healthy diet, as it was believed that sunlight and good nutrition could help combat the disease (Murray, 2015). However, these methods were largely ineffective in curing the disease, and many patients succumbed to its effects.

One of the most common treatments for tuberculosis in the past was the use of sanatoriums, where patients were isolated and given prolonged rest and exposure to fresh air. While this approach was aimed at improving patients' overall health and immune function, it did little to address the underlying cause of the disease (Lienhardt, 2012).

4.1.3 Impact on Society

The impact of tuberculosis on society throughout history has been profound. The disease has long been associated with stigma and fear, leading to social isolation of those affected. In the past, tuberculosis was often viewed as a disease of poverty and overcrowding, as it disproportionately affected marginalized populations living in cramped and unsanitary conditions (Kim, 2015). This stigma further exacerbated the suffering of patients and hindered attempts to mitigate the spread of the disease.

In addition, tuberculosis had significant economic implications, as it often affected individuals in their prime working years, leading to an economic burden on families. Furthermore, the high mortality rates associated with tuberculosis contributed to a sense of fear and helplessness among the population, further perpetuating the cycle of stigma and discrimination (Farmer, 2016).

4.2 Current Status of Tuberculosis

4.2.1 Global Burden of Disease

According to Delobelle (2013), 'Tuberculosis (TB) remains a significant global health concern, with an estimated 10 million new cases and 1.4 million deaths annually. The burden of TB is particularly high in low- and middle-income countries, with countries in sub-Saharan Africa, Southeast Asia, and the Western Pacific region accounting for the majority of the cases. Additionally, the emergence of drug-resistant forms of TB, such as multidrug-resistant TB (MDR-TB) and extensively drug-resistant TB (XDR-TB), further complicates efforts to control the disease'. The high burden of TB has profound social and economic implications for affected communities, exacerbating poverty and hindering development efforts (Behzadifar, 2020).

4.2.2 Risk Factors and Vulnerable Populations

Numerous threat issues contribute to the spread and prevalence of TB. Factors such as poor ventilation and inadequate access to healthcare services increase the risk of TB transmission (Canetti, 2020). Furthermore, socio-economic determinants such as malnutrition, HIV infection, and substance abuse contribute to increased vulnerability to TB. Vulnerable populations such as migrants, prisoners, and individuals living in conflict-

affected regions are disproportionately affected by TB due to limited access to healthcare and social support services. Addressing these risk factors and targeting interventions towards vulnerable populations is essential to reducing the problem of TB (Dias, 2018).

4.2.3 Challenges in Diagnosis and Treatment

Accurate and early detection of tuberculosis is a critical problem in the fight against the illness. The accuracy and specificity of conventional diagnostic techniques, including sputum smear microscopy, are limited, especially when it comes to identifying drug-resistant TB strains (Fox, 2017). In many low-resource settings, access to more modern diagnostic techniques like culture-based procedures and molecular testing (like GeneXpert) is still restricted, which causes delays in the diagnosis and start of therapy (Koul, 2011).

Treatment of TB also poses challenges, especially in the case of ‘drug-resistant TB’. The lengthy and complex treatment regimens for ‘MDR-TB and XDR-TB’ are connected with high proportions of treatment catastrophes and adverse drug reactions. Furthermore, ensuring treatment adherence and monitoring for drug resistance during the course of treatment are critical to achieving successful treatment outcomes (Leung, 2013).

Integrating innovative approaches such as digital health technologies for TB treatment monitoring, community-based TB care models, and patient-centered care initiatives are vital in overcoming these challenges (Ortblad, 2015). Collaborative efforts between governments, healthcare providers, researchers, and community stakeholders are essential in advancing the fight against TB and achieving global TB elimination targets.

4.3 Progress in Tuberculosis Control

4.3.1 Development of Vaccines

The battle against tuberculosis has been significantly bolstered by the development of effective vaccines. The most renowned vaccine for tuberculosis is Bacillus Calmette-Guérin (BCG), which has been in use for nearly a century (Tiberi, 2017). BCG vaccination is known to protect against severe forms of tuberculosis in children and has been a key tool in reducing the problem of the disease in several parts of the world. Despite its efficacy in preventing severe disease, BCG has limitations in protecting against pulmonary TB in grownups, which is the most common form of the disease worldwide (Zumla, 2015).

To address this gap, researchers have been working on developing new and improved vaccines that can provide broader protection against TB. One promising vaccine candidate is MVA85A, which is designed to boost immune responses elicited by BCG (Tiberi, 2017). Clinical trials of MVA85A have shown promising results in terms of enhancing the protective efficacy of BCG. However, challenges remain in developing a vaccine that is highly effective in preventing TB infection and disease in all age groups and populations.

4.3.2 Advances in Drug Therapies

According to Raviglione (2016), ‘The development of effective drug therapies has been a game-changer in the fight against tuberculosis. The standard treatment for TB involves a combination of antibiotics taken for a minimum of six months. This treatment regimen, known as Directly Observed Treatment, Short-course (DOTS), has been instrumental in reducing the burden of TB worldwide. However, the emergence of drug-resistant strains of the bacterium *Mycobacterium tuberculosis*, particularly multidrug-resistant TB (MDR-TB) and extensively drug-resistant TB (XDR-TB), has posed a significant challenge to TB control efforts.’

To address the rising threat of drug-resistant TB, researchers have been working on developing new therapies, such as bedaquiline and delamanid, which have shown promising results in treating MDR-TB. These novel drugs offer new hope for patients with drug-resistant TB who have limited treatment options (Leung, 2013). In addition, efforts are underway to develop more effective cure regimens for TB, as the current six-month

duration of treatment can result in poor treatment adherence and the development of drug resistance.

4.3.3 Strategies for Prevention and Control

In addition to vaccines and drug therapies, effective strategies for prevention and control are essential in the battle against tuberculosis. One key approach is early detection and diagnosis of TB through improved diagnostic tools, such as GeneXpert and molecular diagnostics, which can rapidly detect TB and drug resistance (Lönnroth, 2015). Early diagnosis enables prompt initiation of treatment, which is crucial for preventing the spread of TB within communities.

In addition, initiatives aimed at fortifying tuberculosis control programs—like introducing infection control protocols in medical facilities and advocating for community-based care models—are critical to stopping the spread of tuberculosis (TB) (Kim, 2015). In addition, lowering the risk of tuberculosis transmission and enhancing treatment outcomes depend on tackling socioeconomic determinants of health, including hunger, poverty, and substandard housing.

4.4 Challenges in TB Control

4.4.1 Drug Resistance

Drug resistance remains a significant challenge in the fight against tuberculosis. The development of drug-resistant strains, including ‘multidrug-resistant (MDR-TB)’ and ‘extensively drug-resistant (XDR-TB)’ tuberculosis, presents a serious threat to successful treatment outcomes (Fox, 2017). This resistance is often attributed to suboptimal treatment regimens, inadequate adherence to medications, and inconsistent or incomplete treatment courses. Additionally, the inappropriate use of antibiotics and limited admission to quality healthcare services contribute to the growth of drug-resistant TB strains (Esmail, 2014).

Several studies have highlighted the alarming rise of drug-resistant tuberculosis strains worldwide. For example, a study by Delobelle (2013) reported a global increase in MDR-TB cases, with particularly high rates in Eastern Europe and parts of Asia. This underscores the urgent need for improved surveillance, early detection, and effective treatment strategies to combat drug-resistant TB.

4.4.2 Inadequate access to healthcare services

Limited access to quality healthcare services poses a significant barrier to the control and management of tuberculosis. In many low- and middle-income states, healthcare infrastructure is often under-resourced and unable to provide comprehensive TB diagnosis, treatment, and follow-up care (Canetti, 2020). This leads to delays in diagnosis, poor treatment outcomes, and the potential for ongoing transmission of the disease.

A study by Behzadifar (2020) found that challenges such as shortages of trained healthcare providers and lack of effective referral systems contribute to delayed diagnosis and treatment initiation for TB patients. Addressing these systemic barriers is crucial to enhancing TB control efforts and reducing the overall burden of the disease.

4.4.3 Stigma and Discrimination

Stigma and discrimination surrounding tuberculosis remain pervasive and often act as barriers to timely diagnosis and treatment. Individuals affected by TB may experience social ostracism, employment discrimination, and exclusion from their communities due to misconceptions about the disease (Dye, 2013). This stigma can deter individuals from seeking healthcare services, adhering to treatment, and disclosing their TB status, ultimately hindering attempts to regulate the spread of the disease.

Studies have shown that stigma and discrimination significantly impact TB control efforts. A study by Dias (2018) highlighted the negative consequences of stigma on treatment adherence and outcomes among TB patients. Addressing stigma through community

education, advocacy, and empowerment of TB-affected individuals is essential for promoting early diagnosis, treatment compliance, and successful outcomes.

4.4.4 Social determinants of health

The impact of tuberculosis and the efficiency of control efforts are significantly shaped by the social determinants of health. Poor health outcomes and an increased susceptibility to tuberculosis infection are caused by a number of factors, including poverty, congested living circumstances, inadequate nutrition, and limited access to education and employment opportunities (Farmer, 2016). The TB epidemic is fueled by a complex web of risk factors that are woven together by these social determinants, biological variables, and environmental factors.

Günther (2014) demonstrated the association between poverty and TB prevalence, highlighting the disproportionate burden of the disease among marginalized populations. Addressing social determinants through targeted interventions, policy changes, and public health initiatives is crucial for reducing health inequities and achieving meaningful progress in TB control efforts.

4.5 Future Directions in Tuberculosis Research

4.5.1 Emerging Technologies in Diagnosis

One of the key challenges in the battle against tuberculosis (TB) has been the accurate and timely diagnosis of the disease. However, recent advances in technology have opened up promising avenues for improving TB diagnostics (Koul, 2011). For example, molecular diagnostic tools have revolutionized TB diagnosis in recent years. These technologies have significantly reduced turnaround times for diagnosis and have been instrumental in identifying drug-resistant TB cases early, enabling appropriate treatment to be initiated promptly (Lienhardt, 2012).

Furthermore, the development of innovative diagnostic tools, such as artificial AI algorithms and digital chest X-rays for TB screening, holds significant promise in improving the efficiency and accuracy of TB diagnosis (McMillen, 2015). For instance, AI-powered algorithms can analyze radiographic images for abnormal patterns indicative of TB infection, assisting healthcare providers in making more accurate diagnoses. These technologies can help to address the challenge of under-diagnosis and ensure that TB cases are detected and treated promptly (Ortblad, 2015).

Tandon (2017) highlighted the potential of AI in TB diagnosis, demonstrating high sensitivity and specificity in detecting TB from chest X-ray images. These findings underscore the potential of emerging technologies in transforming TB diagnosis and improving patient outcomes.

4.5.2 Novel Treatment Approaches

Novel therapeutic strategies are essential in the fight against tuberculosis (TB), especially in light of the emergence of ‘drug-resistant strains’ of the bacteria. Diagnostic breakthroughs are also vital. A series of antibiotics are administered over several months as part of traditional TB treatment, which can be difficult for patients to follow and may result in treatment failure (Walzl, 2018). Nonetheless, novel therapeutic candidates, such as bedaquiline and delamanid, present encouraging substitutes for managing drug-resistant tuberculosis. These medications have demonstrated effectiveness in treating multidrug-resistant tuberculosis and may reduce treatment duration and enhance patient outcomes.

Furthermore, research into host-directed therapies (HDTs) is gaining traction as a novel approach to TB treatment. HDTs target the host resistant reaction rather than the microbes themselves, aiming to enhance the body's ability to control TB infection. This next-generation treatment strategy could potentially improve treatment outcomes and reduce the reliance on antibiotics, thereby helping to combat drug resistance in TB (Raviglione, 2016).

Murray (2015) has emphasized the importance of developing new treatment regimens for drug-resistant TB. By exploring novel compounds and treatment strategies, researchers can expand the therapeutic options available for TB patients and improve the overall effectiveness of TB treatment.

4.5.3 Public Health Interventions

Interventions in public health are essential for the prevention of tuberculosis (TB), in addition to improvements in diagnosis and treatment. In order to identify and treat TB cases early and stop the disease from spreading throughout communities, strategies including contact tracing, community-based active case discovery, and focused screening programs are crucial (Lienhardt, 2012). Comprehensive TB control strategies also need to address social determinants of health, guarantee treatment adherence, and increase access to TB care.

To reduce the spread of tuberculosis, improved infection control procedures are essential in both healthcare and crowded settings, such as jails and shelters. In order to reduce the danger of tuberculosis transmission in high-risk environments and safeguard vulnerable people from infection, administrative controls, environmental controls, and respiratory protection measures can be put in place (Kim, 2015).

A study by Esmail (2014) has highlighted the importance of comprehensive TB control strategies that combine prevention, diagnosis, and treatment interventions. By implementing robust public health interventions and addressing social determinants of health, policymakers and healthcare providers can make substantial strides in reducing the burden of TB and achieving global TB elimination targets.

4.5.4 Future Directions in Tuberculosis Research

Moving forward, continued investment in research and innovation is essential for advancing the fight against TB. Collaborative efforts among researchers, healthcare providers, policymakers, and community stakeholders are crucial to developing comprehensive solutions to combat TB effectively (Dye, 2013). Key areas for future research include:

Development of point-of-care diagnostics: Research efforts should focus on developing rapid, affordable, and user-friendly diagnostic gears that can be easily deployed in resource-limited surroundings. Point-of-care tests that can accurately diagnose TB and detect drug resistance in a timely manner are essential for improving access to care and reducing diagnostic delays (Canetti, 2020).

Exploration of novel treatment targets: Research into novel drug targets and therapeutic strategies, such as host-directed therapies and immunomodulators, can help expand the treatment options available for TB patients. Identifying new drug candidates and combination therapies that are effective against drug-resistant TB strains is critical for improving treatment outcomes and reducing the global burden of TB (Dias, 2018).

Strengthening health systems and improving access to care: Efforts to strengthen healthcare organizations, enhance healthcare worker training, and improve access to TB care are essential for achieving TB elimination goals (Günther, 2014). Research that focuses on optimizing healthcare delivery, leveraging digital health technologies, and promoting patient-centered care can help ensure that TB patients receive timely and effective treatment.

5. Conclusion

In conclusion, tuberculosis remains a significant global health challenge despite decades of efforts to control and eliminate the disease. The past successes and lessons learned from these initiatives have paved the way for new strategies and approaches to combat

tuberculosis in the present day. It is clear that a multi-faceted, collaborative approach involving governments, healthcare providers, researchers, and communities is essential in effectively addressing the complex issues surrounding tuberculosis.

Moving forward, it is imperative to prioritize investments in research and innovation to develop new tools, diagnostics, and treatments for tuberculosis. Additionally, efforts to strengthen health systems, improve access to care, and address social determinants of health are crucial for achieving sustainable outcomes in the battle against tuberculosis.

We can work toward a future when tuberculosis is no longer a danger to world health by building on the achievements of the past and tackling the current issues. Together, we can keep battling this old illness and work to eradicate tuberculosis from the planet.

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