Chapter 10
Machine Learning for Tuberculosis Diagnosis: Methods, Challenges, and Opportunities

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ABSTRACT

Tuberculosis (TB) remains a major global health concern, especially in low- and middle-income countries. Conventional diagnostic methods, such as sputum microscopy and chest X-ray, face challenges like delays, human error, and limited accessibility. Machine learning (ML) offers a promising solution to improve diagnostic accuracy, speed decision-making, and assist resource-constrained healthcare settings. This chapter explores ML techniques for TB diagnosis, from classical algorithms like Support Vector Machines to advanced models such as Convolutional Neural Networks (CNNs). It covers data collection, preprocessing, model evaluation, and real-world case studies, while addressing issues of data quality, interpretability, and ethics. By mapping current progress and future directions, the chapter highlights ML's transformative role in TB diagnostics and advocates for AI applications that ensure transparency, equity, and contextual relevance in healthcare.

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INTRODUCTION

The Global Burden of Tuberculosis (TB)

Tuberculosis (TB) is one of the most destructive infectious diseases in the world and one of the top 10 causes of death worldwide. Despite the development of drugs to treat TB many decades ago, TB persists in impoverished nations and continues to infect and kill people, especially in low- and middle-income countries, where there is limited access to timely diagnosis and treatment. The World Health Organization (WHO) estimated that there will be 10.6 million new TB cases in 2023, killing more than 1.3 million (Lundberg *et. al.,* 2017).

The burden is shown not only in mortality but also in the social and economic costs to families and health systems, which are disproportionately felt by those living in poverty and overcrowded housing and with weakened immunity. Of concern is the emergence of Multidrug-Resistant TB (MDR-TB), which does not respond to usual first-line drugs and is complicated, costly, and longer to treat than other forms of TB. This further puts pressure on already stretched health systems.

What makes TB intimidating is its ability to lie in ambush for unknown periods - latent TB can be in your system for years before activation. This makes monitoring and early treatment difficult. In addition, global mobility and urbanization, along with health inequity, have made TB a disease that cannot be completely controlled, and this is why we need new strategies and tools to confront it.

Need for Advanced Diagnostic Tools

Diagnosing TB in a Timely and accurate manner is vital for successful TB control. Unfortunately, some people still use decades-old diagnostic methods such as sputum smear microscopy and culture-based tests, which have inherent limitations. Although these diagnostic standards of care have been used for many decades and have been the gold standard diagnostics, they are often slow, labor-intensive, and require adequate laboratory, trained staff, and appropriate patient samples, which may not be available in low-resource or rural areas.

Molecular diagnostics based on assays such as the GeneXpert MTB/RIF assay represent a clear advance in space because they significantly reduce the time to diagnosis and allow greater detection of drug resistance. However, even these sophisticated tools have the challenges of cost, maintenance, and availability in parts of the world that are most affected by the disease. Many of the settings where TB is most common have the additional complication of outage in power systems, supply chain fluctuations, and a lack of expertise compound delays in the use of molecular devices and the appropriate use of these tests (Mussie, 2023).