Mycobacterial Diseases
ISSN: 2161-1068
OPEN ACCESS Freely available online
Opinion Article

Microbial Resilience and Human Vulnerability in Tuberculosis

Jose Ancizu*

Department of Medicine, University of Cadiz, Cadiz, Spain

DESCRIPTION

The Tuberculosis disease spectrum ranges from Latent Tuberculosis Infection (LTBI) to active TB disease. Most infected individuals remain asymptomatic, with the pathogen contained within granulomas. These immune-formed structures act as a advantage, confining the bacteria while creating a microenvironment that supports their persistence. However, in some individuals, granuloma stability breaks down, leading to bacterial proliferation and active disease. The shift from latency to active TB is influenced by various factors, including immune suppression (e.g., HIV co-infection), malnutrition, diabetes, and genetic predispositions. The interplay between *Mycobacterium tuberculosis* (*M. tb*) and the host immune system determines whether the infection remains controlled or progresses to disease.

Formation of granulomas

Mycobacterium tuberculosis (*M. tb*) enters the human body *via* inhalation of infectious aerosols. Upon reaching the alveoli, it encounters alveolar macrophages, its primary host cells. These macrophages recognize the pathogen through Pattern Recognition Receptors (PRRs) like Toll Like Receptors (TLRs) and Nod Like Receptors (NLRs). This interaction triggers phagocytosis, aiming to neutralize the bacteria. However, *M. tb* has evolved mechanisms to survive and thrive within macrophages. It inhibits phagosome-lysosome fusion, preventing bacterial degradation. Additionally, it manipulates host cell signalling to avoid immune detection and harnesses host lipids for sustenance. This marks the beginning of a prolonged and intricate host-pathogen battle. Granulomas are feature structures in TB pathology. They consist of macrophages, T cells, B cells, fibroblasts, and other immune cells clustered around infected cells. Granulomas aim to contain *M. tb* and prevent systemic spread. During granuloma formation, infected macrophages release chemokines that recruit additional immune cells to the infection site. T-helper 1 (Th1) cells, particularly those producing Interferon-gamma (IFN-γ), play a pivotal role in activating macrophages to enhance their bactericidal capacity. Simultaneously, regulatory Tregs cells (T cells) modulate the immune response, preventing excessive tissue damage but potentially aiding bacterial persistence. *M. tb* exploits granulomas for its benefit. It can enter a dormant state within granulomas, shielded from immune attacks and antibiotics. This dormant state is a significant barrier to TB eradication, as dormant bacteria can reactivate years later.

Tissue damage in active TB

In active TB, the breakdown of granulomas leads to tissue destruction and bacterial dissemination. Caseation necrosis, a feature of TB, results from an intense immune response that kills infected cells but also damages surrounding tissue. This necrotic core provides a nutrient-rich environment for bacterial replication. The release of proteases and Reactive Oxygen Species (ROS) during the immune response contributes to tissue destruction. Simultaneously, *M. tb* promotes inflammation by inducing cytokine production, exacerbating tissue damage and facilitating bacterial spread. Host genetic factors significantly influence susceptibility to TB. Polymorphisms in genes related to immune signalling pathways, such as IFN-γ, TNF-α, and IL-12, can impact the ability to control *M. tb* infection. Furthermore, genetic predispositions may dictate the nature of granulomas and the likelihood of progression from latent to active TB. Immune regulation is also important, while a robust immune response is essential to controlling *M. tb*, excessive inflammation can lead to pathological damage. Balancing pro-inflammatory and anti-inflammatory responses is vital for limiting tissue destruction while maintaining effective pathogen control.

Treatment and Prevention of TB Pathogenesis

Host pathogen interactions in TB is challenging due to the complexity of human tissues and the variability among individuals. Advances in imaging technologies, such as Positron Emission Tomography-Computed Tomography (PET-CT) scans, and molecular tools, like single-cell RNA sequencing, are providing new insights into granuloma dynamics and immune responses at the cellular level. Animal models and *in vitro* systems have been instrumental in TB research, but they have limitations in replicating the full spectrum of human TB pathology. *Ex vivo* studies using human lung tissue and advanced organoid models are bridging these gaps, offering a more comprehensive

Correspondence to: Jose Ancizu, Department of Medicine, University of Cadiz, Cadiz, Spain, Email: anczsej@outlook.com

Received: 25-Nov-2024, Manuscript No. MDTL-24-35983; **Editor assigned:** 27-Nov-2024, PreQC No. MDTL-24-35983 (PQ); **Reviewed:** 11-Dec-2024, QC No. MDTL-24-35983; **Revised:** 18-Dec-2024, Manuscript No. MDTL-24-35983 (R); **Published:** 24-Dec-2024, DOI: 10.35248/2161-1068.24.14.529

Citation: Ancizu J (2024). Microbial Resilience and Human Vulnerability in Tuberculosis. Mycobact Dis. 14:529.

understanding of M. *tb*-host interactions. Understanding the interactions between M. *tb* and human tissues opens new avenues for TB treatment and prevention. Targeting bacterial survival mechanisms within macrophages, enhancing granuloma stability, and modulating host immune responses are promising strategies. Immunotherapy, combined with traditional antibiotics, may offer better outcomes, especially for drug-resistant TB. Vaccination remains an essential tool for TB control. The Bacille Calmette Guerin (BCG) vaccine provides partial protection, particularly against severe forms of TB in children. However, its efficacy against pulmonary TB in adults is limited. Ongoing research into novel TB vaccines aims to elicit stronger and more durable immune responses.

CONCLUSION

The interplay between M. *tb* and the human host is a finely balanced dynamic that determines the outcome of infection. By solving the complexities of host-pathogen interactions along the TB spectrum, researchers can identify new targets for intervention and develop strategies to curb the global TB burden. Enhanced understanding, combined with innovative technologies, offers hope for a future where TB is no longer a major threat to public health.