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Tuberculosis at the human-animal interface: Epidemiology and control strategies: A review

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Abstract
Tuberculosis (TB) remains a major global health threat affecting both humans and animals, particularly in regions where close interaction occurs at the human-animal interface. Members of the *Mycobacterium tuberculosis* complex (MTBC), especially *Mycobacterium bovis*, contribute significantly to the burden of zoonotic TB, presenting challenges for disease surveillance and control. This review synthesizes existing knowledge on the etiology, historical development, epidemiology, transmission dynamics, public health implications, and prevention strategies for TB at the human-animal interface within a One Health framework. The objective is to provide an integrated assessment of the disease across species and highlight persistent gaps that hinder effective control.
A narrative review methodology was employed, drawing from peer-reviewed articles, international guidelines, and global health reports. Findings indicate that *M. bovis* continues to circulate in livestock, wildlife, and human populations, particularly in low- and middle-income countries where close contact with animals and consumption of unpasteurized milk remain common. Wildlife reservoirs such as badgers, deer, and wild boar complicate eradication efforts by perpetuating transmission cycles. In humans, *M. bovis* infections are clinically similar to those caused by *M. tuberculosis*, leading to diagnostic difficulties and underreporting. Socioeconomic factors, limited veterinary services, and inadequate surveillance systems further amplify the disease burden.
Control strategies such as milk pasteurization, routine cattle testing, culling of infected animals, and wildlife management remain central but are insufficient in isolation. A One Health approach integrating veterinary, medical, and environmental interventions is essential for sustainable reduction of zoonotic TB. Future priorities include development of improved diagnostics, advancement of cattle vaccines, and enhancement of coordinated surveillance systems across species. Strengthening public health education and policy implementation remains critical to reducing transmission risks and safeguarding both human and animal health.

Keywords: Tuberculosis, *Mycobacterium bovis*, zoonosis, one health, bovine tuberculosis, wildlife reservoirs, transmission dynamics, public health

Introduction

Tuberculosis (TB) remains one of the most significant infectious diseases affecting humans and animals globally (WHO, 2023) [5].
The human-animal interface plays a crucial role in the transmission and maintenance of TB, especially in regions where close contact exists between livestock, wildlife, and people (OIE, 2021) [3]. Mycobacterium tuberculosis complex (MTBC) organisms circulate between species, creating unique epidemiological challenges (Khan *et al*., 2021) [2].
Bovine tuberculosis (bTB) caused by *Mycobacterium bovis* is one of the most important zoonoses due to its impact on public health, livestock productivity, and trade (Good & Duignan, 2020) [1].
Understanding the transmission dynamics, risk factors, and control strategies at this interface is essential for designing effective One Health approaches (Rahman *et al*., 2022) [4].

Etiology

Tuberculosis in animals and humans is primarily caused by species within the Mycobacterium tuberculosis complex (MTBC), (Good & Duignan, 2020) [1].

Major members include *M tuberculosis*, *M. bovis*, *M. caprae*, *M. africanum*, and *M. orygis* (Khan *et al*., 2021) [2].
Mycobacterium bovis is the principal pathogen responsible for bovine tuberculosis but can also infect humans, pets, and a wide range of wildlife (OIE, 2021) [3].
The organism is acid-fast, slow-growing, and survives for long periods in the environment under favorable conditions (Rahman *et al*., 2022) [4].
The zoonotic nature of *M. bovis* makes it a critical pathogen at the human-animal interface (WHO, 2023) [5].

History
Tuberculosis has been recognized since ancient times, with skeletal lesions found in Egyptian mummies dating back thousands of years (Khan *et al*., 2021) [2].
Robert Koch's discovery of Mycobacterium tuberculosis in 1882 marked a turning point in TB research (Good & Duignan, 2020) [1].
The zoonotic potential of *M. bovis* was established in the early 20th century when milk-borne transmission to humans was well documented (OIE, 2021) [3].
The introduction of milk pasteurization significantly reduced human infections with *M. bovis* in developed countries (WHO, 2023) [5].
Despite control achievements, bovine TB continues to persist in many developing regions due to inadequate surveillance and animal health infrastructure (Rahman *et al*., 2022) [4].

Epidemiology
Tuberculosis remains endemic in many low- and middle-income countries where livestock and humans often share close environments (WHO, 2023) [5].
Bovine TB affects cattle, buffaloes, goats, pigs, and several wildlife reservoirs, including badgers, deer, possums, and wild boar (Good & Duignan, 2020) [1].
In humans, *M. bovis* accounts for a small but significant percentage of TB cases, particularly in regions with unpasteurized milk consumption (Rahman *et al*., 2022) [4].
Wildlife reservoirs complicate eradication efforts by serving as persistent sources of infection to cattle (OIE, 2021) [3].
Socioeconomic factors such as poverty, limited veterinary services, and traditional livestock management practices influence transmission rates (Khan *et al*., 2021) [2].
A One Health epidemiological approach is essential to understand and manage the interconnected disease patterns between species (WHO, 2023) [5].

Pathogenesis and Transmission
Transmission of *M. bovis* most commonly occurs through inhalation of infected aerosols from coughing animals (Good & Duignan, 2020) [1].
Ingestion of contaminated milk or dairy products is a major route of zoonotic infection in humans, especially children (WHO, 2023) [5].
Cutaneous and congenital transmissions, although rare, have also been reported (Khan *et al*., 2021) [2].
Once inhaled or ingested, the bacteria are phagocytosed by macrophages, where they survive and replicate due to their ability to evade host immunity (Rahman *et al*., 2022) [4].
Granuloma formation occurs as the host attempts to contain the infection, but latency or progression to active disease depends on immune status (Good & Duignan, 2020) [1].
Wildlife reservoirs transmit TB through direct contact, shared feeding areas, and environmental contamination (OIE, 2021) [3].

Public Health Significance
Tuberculosis at the human-animal interface poses significant public health challenges due to the zoonotic potential of *M. bovis* (WHO, 2023) [5].
Human infections with *M. bovis* are clinically indistinguishable from those caused by M. tuberculosis, making diagnosis difficult (Khan *et al*., 2021) [2].
Consumption of raw milk and close contact with infected livestock increase zoonotic risk, especially in pastoral and rural communities (Rahman *et al*., 2022) [4].
Immunocompromised individuals, such as those with HIV, are at higher risk of severe disease from *M. bovis* (WHO, 2023) [5].
The disease has economic consequences through reduced livestock productivity, trade restrictions, and increased costs of control programs (Good & Duignan, 2020) [1].
The One Health perspective highlights the need for integrated veterinary, medical, and environmental interventions (OIE, 2021) [3].

Signs and Symptoms
In cattle, bovine TB often presents with progressive weight loss, chronic cough, lymph node enlargement, and respiratory distress in advanced cases (Good & Duignan, 2020) [1].
Many infected animals remain asymptomatic for long periods, complicating detection (OIE, 2021) [3].
In humans, symptoms caused by *M. bovis* resemble typical TB, including chronic cough, fever, night sweats, and weight loss (WHO, 2023) [5].
Extrapulmonary manifestations are more common in *M. bovis* infections, particularly involving lymph nodes and the gastrointestinal tract (Khan *et al*., 2021) [2].
Delayed diagnosis contributes to disease progression and increased transmission risk (Rahman *et al*., 2022) [4].

Prevention and Control
Pasteurization of milk remains one of the most effective ways to prevent zoonotic TB in humans (WHO, 2023) [5].
Regular tuberculin skin testing and culling of infected cattle are standard control strategies in many countries (Good & Duignan, 2020) [1].
Movement control and quarantine help reduce disease spread between herds (OIE, 2021) [3].
Wildlife management, including fencing, habitat modification, and vaccination, is essential in regions with wildlife reservoirs (Rahman *et al*., 2022) [4].
Public awareness programs focusing on safe milk consumption and animal handling reduce human exposure (WHO, 2023) [5].
A One Health approach integrating veterinary, medical, and environmental interventions is critical for sustainable control (Khan *et al*., 2021) [2].

Conclusions and Future Prospects
Tuberculosis at the human-animal interface remains a major global health issue requiring collaborative One Health interventions (WHO, 2023) [5].
Control efforts must address challenges such as wildlife reservoirs, limited diagnostics, and resource constraints in endemic areas (OIE, 2021) [3].
Prospects include improved molecular diagnostics, development of effective cattle vaccines, and strengthening cross-sector surveillance systems (Rahman *et al*., 2022) [4].

Greater investment in public health education and policy implementation is essential for reducing zoonotic transmission (Good & Duignan, 2020) [1].

Overall, integrating veterinary and human health strategies offers the best pathway toward long-term TB reduction (Khan *et al*., 2021) [2].

Conflict of Interest

Not available

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Reference

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