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Rabies: A comprehensive review from a veterinary public health and epidemiological perspective

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Abstract
Rabies is a fatal viral zoonosis of major global public health concern (WHO, 2023) [3]. Rabies virus primarily affects mammals and is responsible for tens of thousands of human deaths each year, mostly in Asia and Africa (CDC, 2022) [1]. Veterinary public health plays a critical role in surveillance, control, and prevention of rabies transmission at the animal-human interface (WOAH, 2021) [4]. The disease remains endemic in many low- and middle-income countries due to gaps in vaccination coverage, poor surveillance, and limited access to post-exposure prophylaxis (WHO, 2023) [3]. This review provides updated insights into the etiology, epidemiology, transmission, clinical features, diagnosis, and preventive strategies of rabies, with emphasis on future prospects within veterinary public health.

Keywords: Comprehensive review, veterinary public health, epidemiological perspective

Introduction
Rabies is a universally fatal viral encephalitis caused by lyssaviruses, posing significant health and economic burdens worldwide (WHO, 2023) [3]. Despite being vaccine-preventable, rabies continues to affect vulnerable populations, especially children in rural areas (CDC, 2022) [1]. Veterinary public health interventions, including mass dog vaccination and surveillance, are crucial for controlling the disease (WOAH, 2021) [4]. Understanding the epidemiological patterns and pathogenic mechanisms is essential for optimizing prevention strategies (Hampson *et al.*, 2020) [2].

History
Rabies has been recognized since ancient civilizations, with descriptions found in Mesopotamian and Greek texts (WHO, 2023) [3]. Louis Pasteur developed the first rabies vaccine in 1885, revolutionizing prevention and treatment (CDC, 2022) [1]. Over time, global health organizations have implemented strategies to eliminate dog-mediated human rabies, though challenges persist (WOAH, 2021) [4].

Etiology
Rabies is caused by the Rabies virus, a negative-sense single-stranded RNA virus belonging to the genus *Lyssavirus* within the family *Rhabdoviridae* (WHO, 2023) [3]. Multiple lyssavirus species exist, but classical rabies virus remains the primary agent in human and animal cases (CDC, 2022) [1].

Epidemiology
Rabies is endemic in more than 150 countries, with over 59,000 human deaths annually (WHO, 2023) [3]. Domestic dogs account for over 99% of human rabies transmissions in endemic regions (CDC, 2022) [1]. Wildlife reservoirs such as bats, foxes, and raccoons contribute to disease persistence, especially in the Americas and Europe (WOAH, 2021) [4]. Socioeconomic factors, vaccination gaps, and limited diagnostic capacity influence disease distribution (Hampson *et al.*, 2020) [2].

Transmission and Pathogenesis
Rabies is transmitted primarily through the bite of an infected animal, as the virus is abundant in saliva (CDC, 2022) [1]. Following entry, the virus replicates in muscle cells before traveling via peripheral nerves to the central nervous system (WHO, 2023) [3]. Once the virus reaches the brain, it causes severe encephalitis, ultimately leading to coma and death (WOAH, 2021) [4]. The virus subsequently migrates to salivary glands, facilitating further transmission (Hampson *et al*., 2020) [2].

Public Health Significance
Rabies poses a major global health threat due to its high fatality rate and substantial economic impact (WHO, 2023) [3]. Preventive measures, including dog vaccination and post-exposure prophylaxis, are cost-effective and essential for reducing human deaths (CDC, 2022) [1]. The "Zero by 30" initiative aims to end dog-mediated human rabies by 2030 through One Health collaboration (WOAH, 2021) [4].

Symptoms
Rabies symptoms progress from nonspecific signs such as fever, headache, and malaise to neurological manifestations including hydrophobia, agitation, and paralysis (WHO, 2023) [3]. Two major forms exist: furious rabies characterized by hyperactivity, and paralytic rabies marked by ascending flaccid paralysis (CDC, 2022) [1]. Once clinical signs appear, the disease is almost invariably fatal (WOAH, 2021) [4].

Diagnosis
Laboratory diagnosis of rabies includes detection of viral antigen using the direct fluorescent antibody test, which remains the gold standard (WHO, 2023) [3]. Molecular methods such as RT-PCR enable rapid and sensitive detection in both humans and animals (CDC, 2022) [1]. Immunohistochemistry and serology also support diagnosis in specific contexts (WOAH, 2021) [4].

Prevention and Control
Mass dog vaccination is the most effective strategy for controlling rabies transmission at the population level (WHO, 2023) [3]. Post-exposure prophylaxis, including wound cleaning, vaccination, and administration of rabies immunoglobulin, prevents disease development in exposed individuals (CDC, 2022) [1]. Strengthening surveillance, improving laboratory capacity, and promoting community awareness are essential components of rabies control programs (WOAH, 2021) [4]. One Health approaches integrating human, animal, and environmental health sectors enhance long-term sustainability of rabies elimination strategies (Hampson *et al*., 2020) [2].

Conclusions and Future Prospects
Rabies remains a persistent global health threat despite the availability of effective vaccines (WHO, 2023) [3]. Strengthening veterinary public health systems, improving surveillance, and achieving high vaccination coverage in dog populations are crucial for elimination (CDC, 2022) [1]. Future research should focus on improved oral vaccines, rapid diagnostic tools, and integrated One Health systems to support sustainable control (WOAH, 2021) [4]. Continued global commitment is essential to achieving the goal of eliminating dog-mediated human rabies by 2030 (Hampson *et al*., 2020) [2].

Conflict of Interest
Not available

Financial Support
Not available

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