

One Health Approach to Dog-Mediated Rabies Elimination in India: Evidence, Implementation Challenges and the Path to Zero by 30

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Abstract

Rabies is a neglected but almost invariably fatal zoonotic disease that remains endemic in many parts of Asia and Africa despite the availability of highly effective vaccines and established preventive interventions. Dog-mediated rabies accounts for the overwhelming majority of human rabies infections, making control of the canine reservoir central to achieving sustainable elimination. Although timely post-exposure prophylaxis (PEP) can prevent disease following exposure, reliance on human PEP alone does not interrupt transmission at its source. The persistence of rabies therefore reflects not simply a lack of biomedical tools but gaps in implementation, surveillance, canine vaccination coverage, healthcare accessibility, community engagement and coordination among responsible sectors. The One Health approach provides an integrated framework linking human health, animal health and environmental determinants to address these interconnected challenges. This review examines the role of mass dog vaccination, responsible dog population management, PEP, surveillance, community participation, environmental management, economic considerations and multisectoral governance in rabies elimination. Particular attention is given to the Indian context, where the National Action Plan for Rabies Elimination (NAPRE) seeks to achieve elimination of dog-mediated human rabies by 2030. Recent evidence indicates that fragmented governance, inadequate canine vaccination coverage, inequitable access to PEP and weak integration of surveillance remain major barriers to achieving this target. Emerging evidence from India also demonstrates the feasibility of integrating rabies vaccination with existing veterinary and public-health programmes and strengthening surveillance through public-private collaboration. The review proposes an integrated framework based on six interconnected pillars—Prevent, Protect, Predict, Participate, Partner and Progress—to translate the One Health concept into an operational rabies-elimination strategy. Achieving Zero by 30 will require sustained political commitment, adequate financing, high-quality canine vaccination, equitable access to PEP, integrated surveillance and meaningful participation of communities and local authorities.

Keywords: Rabies; One Health; canine vaccination; post-exposure prophylaxis; dog-mediated rabies; India; Zero by 30; NAPRE; Six Pillars.

Introduction

Rabies is an acute, progressive and almost invariably fatal viral encephalitis caused

by viruses of the genus *Lyssavirus*. It remains a major neglected zoonotic disease, particularly in Asia and Africa, despite the availability of

effective vaccines and well-established preventive measures. The World Health Organization (WHO) reports that rabies occurs in more than 150 countries and territories and causes tens of thousands of human deaths annually, with approximately 40% of affected individuals being children below 15 years of age. (World Health Organization, 2024)

Rabies infects mammals, including dogs, cats, livestock and wildlife. Rabies spreads to people and animals via saliva, usually through bites, scratches, or direct contact with mucosa (e.g. eyes, mouth, or open wounds). Once clinical symptoms appear, rabies is virtually 100% fatal. (World Health Organization, 2024)

The global cost of rabies is estimated to be around US\$ 8.6 billion per year including lost lives and livelihoods, medical care and associated costs, as well as uncalculated psychological trauma. Rabies is present on all continents except Antarctica. Globally there are an estimated 59 000 deaths from rabies annually; however, due to underreporting, documented case numbers often differ from the estimate. However, timely wound management and appropriate PEP can prevent progression to disease following exposure. As of 2018, the average estimated cost of rabies post-exposure prophylaxis (PEP) was US\$ 108 (along with travel costs and loss of income), which can be a financial burden on those earning US\$ 1–2 per person, daily. Over 29 million people worldwide receive human rabies vaccine annually. These findings are particularly important because they demonstrate that rabies elimination is not simply a question of whether effective vaccines exist. It is a question of whether those vaccines and associated services reach the appropriate animal and human populations at the required scale and time. (World Health Organization, 2024; Blumberg, 2024)

Rabies therefore represents a model disease for the application of the **One Health approach**. Human infection is directly linked to animal infection, while animal populations are influenced by environmental conditions, human behaviour, municipal management,

socioeconomic circumstances and community practices. A free-roaming dog population, for example, is not exclusively a veterinary issue. Its size, distribution and behaviour can be influenced by food availability, waste disposal, abandonment, ownership practices, urban development and local governance. Similarly, a dog-bite victim is not solely a medical case: the biting animal may represent an epidemiological signal requiring veterinary assessment and potentially triggering further interventions in the community. (Acharya et al., 2020; Zha et al., 2025; Nujum et al., 2024)

The global commitment to eliminate human deaths from dog-mediated rabies by 2030, known as **Zero by 30**, provides an international framework for this approach. The strategy developed through collaboration among WHO, the Food and Agriculture Organization of the United Nations (FAO), the World Organisation for Animal Health (WOAH) and the Global Alliance for Rabies Control (GARC) emphasizes vaccination of dogs, prevention and management of human exposures, surveillance, awareness and strengthening of health systems. However, important gaps remain between the conceptual promise of One Health and its operational implementation. Much of the literature evaluates individual interventions—such as dog vaccination or PEP—rather than examining how multiple interventions can be connected through shared surveillance, governance, financing and accountability. This distinction is particularly important in countries such as India, where national policies exist but implementation varies between states and districts. (World Health Organization, 2024; Acharya et al., 2020)

Sources and Transmission

In the Americas, where dog-mediated rabies is mostly controlled, hematophagous (blood-feeding) bats are now the primary source of human rabies. Human deaths following exposure to foxes, raccoons, skunks, and other wild mammals are very rare, and bites from rodents are not known to transmit rabies. Contraction of rabies through inhalation of virus-containing aerosols, consumption of raw

meat or milk of infected animals, or through organ transplantation is extremely rare. Human-to-human transmission through bites or saliva is theoretically possible but has never been confirmed. (World Health Organization, 2024)

Symptoms

The incubation period for rabies is typically 2–3 months but may vary from one week to one year, depending on factors such as the location of virus entry and the viral load. Initial symptoms of rabies include generic signs like fever, pain and unusual or unexplained tingling, pricking, or burning sensations at the wound site. As the virus moves to the central nervous system, progressive and fatal inflammation of the brain and spinal cord develops. Clinical rabies in people can be managed but very rarely cured, and not without severe neurological deficits. (World Health Organization, 2024)

Rabies as a One Health Disease

The One Health approach recognizes that human health is closely linked to animal health, ecosystem conditions and social systems. Rabies demonstrates this relationship because disease transmission occurs at the human–animal interface, while its prevention requires coordinated action from veterinary services, public health departments, local authorities, laboratories and communities. (Acharya et al., 2020; Zha et al., 2025; Nujum et al., 2024)

The veterinary sector is responsible for animal vaccination, animal-bite investigation, surveillance, diagnosis and management of suspected rabid animals. The human healthcare sector provides wound management, PEP, clinical care and reporting of suspected human cases. Environmental and municipal authorities contribute through waste management, responsible dog population management and reduction of conditions that support large populations of free-roaming dogs. Therefore, rabies control cannot be sustained through isolated interventions by a single department. (Acharya et al., 2020; Zha et al., 2025; Yale et al., 2022)

Interconnection Between Animal, Human and Environment

1. Animal Health

Dogs and other susceptible mammals act as reservoirs or hosts for rabies virus. Mass dog vaccination, responsible ownership, animal-bite investigation and veterinary surveillance are essential for reducing transmission. (World Health Organization, 2024; Acharya et al., 2020; Yale et al., 2022)

2. Human Health

People exposed to potentially rabid animals require immediate risk assessment, wound washing and timely PEP. Public awareness and accessible healthcare services help prevent avoidable deaths. (World Health Organization, 2024; Nadal et al., 2023)

3. Environmental and Social Health

Waste disposal, urban planning, community behavior, access to veterinary services and local governance influence interactions between free-roaming dogs and people. (Acharya et al., 2020; Zha et al., 2025; Nujum et al., 2024)

Canine Vaccination

Dogs are responsible for nearly all human rabies transmission in many endemic settings; canine vaccination offers most direct means of interrupting the transmission cycle. (World Health Organization, 2024; Acharya et al., 2020; Yale et al., 2022)

PEP is reactive: It is administered after individual has already experienced a potential exposure.

Dog vaccination is preventive: It reduces the probability that exposure will occur in first place.

Human Post-Exposure Prophylaxis

PEP generally involves:

1. immediate and thorough wound washing;
2. appropriate rabies vaccination;
3. administration of rabies immunoglobulin or another recommended passive immunization product when indicated.

Access of PEP

A vaccine that exists but cannot be reached by an exposed person is effectively

unavailable. (World Health Organization, 2024; Nadal et al., 2023)

Barriers to PEP can include:

- geographical distance;
- treatment costs;
- inadequate awareness;
- vaccine stock-outs;
- difficulty accessing immunoglobulin;
- incomplete treatment;
- delayed healthcare seeking;
- inadequate referral systems.

The 2025 Indian nationwide study provides particularly important evidence. Among people reporting dog bites, approximately 20.5% did not receive anti-rabies vaccination, while only 66.2% received at least three doses. Among those who initiated vaccination with one dose, nearly half did not complete the full course. (Thangaraj et al., 2025)

Environmental Determinants of Rabies Risk

The environmental component of One Health is often less developed than the animal and human components. (Acharya et al., 2020; Zha et al., 2025; Nujum et al., 2024)

However, the environment can influence rabies risk indirectly through dog ecology and human–animal interaction. (Acharya et al., 2020; Zha et al., 2025; Nujum et al., 2024)

Potential factors include:

- unmanaged solid waste;
- food availability;
- urban expansion;
- density of free-roaming dogs;
- housing patterns;
- livestock–dog interaction;
- local animal-management practices.

Environmental interventions should be evaluated carefully. They should complement rather than replace vaccination and PEP. (Acharya et al., 2020; Zha et al., 2025; Yale et al., 2022)

India: The Current Challenge

India occupies a central position in global rabies elimination because of its large population, substantial dog-bite burden and continued occurrence of human rabies. (World Health Organization, 2024; Thangaraj et al., 2025; Phukan, 2026)

The 2025 nationwide burden study provides some of the most important recent evidence. Across the surveyed population, animal bites were common and dogs accounted for most exposures. The study estimated approximately 9.1 million animal bites and 5,726 human rabies deaths annually. Importantly, incomplete PEP and insufficient vaccination coverage were identified as barriers to elimination. (Thangaraj et al., 2025)

These findings have several implications.

1. Surveillance estimates matter because historical estimates may substantially underrepresent the current burden.

2. The elimination strategy must be national but implemented locally.

3. Human and veterinary systems must share information.

4. PEP coverage and completion need to become measurable programme indicators.

5. Dog vaccination must be sustained rather than implemented as sporadic campaigns.

India's National Action Plan for Dog-Mediated Rabies Elimination (NAPRE) provides the policy framework for achieving elimination by 2030 (Also known as Zero by 30). Recent policy discussions emphasize that a coordinated One Health response is necessary for India to reach this target. (Phukan, 2026; Gibson et al., 2022)

The Six-Pillar One Health Framework

One Health rabies programme can be organized around six interconnected pillars. (Acharya et al., 2020; Zha et al., 2025; Nujum et al., 2024)

1. PREVENT

Prevent exposure and transmission through: Sustained canine vaccination; Responsible ownership; Humane dog population management; Vaccination of appropriate animal reservoirs; Environmental management; Bite-prevention education. (Acharya et al., 2020; Yale et al., 2022; Phukan, 2026; Gibson et al., 2022)

2. PROTECT

Protect exposed individuals through: Immediate wound washing; Timely PEP; Appropriate vaccination; Passive immunization when indicated; Targeted PrEP

for appropriate high-risk groups. (World Health Organization, 2024; Nadal et al., 2023)

3. PREDICT

Strengthen early detection through: integrated human surveillance; Animal surveillance; Laboratory diagnosis; GIS mapping; Digital reporting; Monitoring of vaccination coverage. (Acharya et al., 2020; Zha et al., 2025; Phukan, 2026; Gibson et al., 2022)

4. PARTICIPATE

Engage: communities; schools; dog owners; local leaders; veterinarians; health workers; animal-welfare organizations. (Acharya et al., 2020; Zha et al., 2025; Nujum et al., 2024)

5. PARTNER

Create formal collaboration between: Veterinary services + Human health + Municipal authorities + Environmental agencies + Laboratories + Research institutions + Communities (Acharya et al., 2020; Zha et al., 2025; Nujum et al., 2024; Phukan, 2026)

6. PROGRESS

Measure:

Dog vaccination coverage; Dog-bite incidence; PEP initiation; PEP completion; PEP accessibility; Laboratory-confirmed animal cases; Human rabies deaths; Surveillance completeness; Programme cost; Geographic coverage. (Acharya et al., 2020; Zha et al., 2025; Phukan, 2026)

Major Challenges to Implementation

1. Inadequate canine vaccination coverage
2. Unequal PEP access
3. Weak surveillance
4. Fragmented governance
5. Limited laboratory capacity
6. Incomplete community engagement
7. Insufficient long-term financing
8. Data quality
9. Sustainability

Policy Recommendations

1. Establish clear multisectoral accountability so that each agency has defined responsibilities and measurable targets.
2. Maintain sustained mass dog vaccination with reliable monitoring of

coverage rather than relying on one-time campaigns

3. Integrate human and animal surveillance so that dog-bite events trigger appropriate veterinary and public-health responses.
4. Strengthen field-veterinary capacity, particularly in rural and underserved regions.
5. Improve equitable access to PEP, particularly in remote populations.
6. Use existing veterinary and public-health infrastructure wherever feasible to reduce duplication and improve programme efficiency
7. Strengthen community participation and responsible dog ownership.
8. Integrate environmental management, particularly waste management and local dog-population ecology, into municipal rabies programmes.
9. Develop measurable district-level indicators for canine vaccination, PEP accessibility, surveillance and human rabies outcomes.
10. Evaluate innovative vaccination approaches, including oral vaccination for appropriate free-roaming dog populations.

Conclusion

Rabies remains a major public health concern in India despite the availability of effective preventive measures. Its control requires a coordinated One Health approach involving human health, animal health and environmental management. Mass dog vaccination, timely post-exposure prophylaxis (PEP), community participation, environmental management and effective governance are important components of rabies prevention. In India, inadequate vaccination coverage, limited access to PEP, weak surveillance and poor coordination between sectors remain major challenges. The One Health approach provides a framework for addressing these challenges through cooperation among veterinary services, healthcare professionals, government authorities and communities. The proposed six-

pillar framework—Prevent, Protect, Predict, Participate, Partner and Progress—highlights the importance of integrating these efforts. Strengthening coordination and ensuring the effective implementation of existing rabies-control measures are essential for progressing towards India's target of eliminating dog-mediated human rabies by 2030.

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