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Rabies Elimination by 2030: A Comprehensive Review of Veterinary Approaches and Gaps Worldwide

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ABSTRACT

By 2030, the World Health Organization, World Organization for Animal Health, and Food and Agriculture Organization hope to eradicate dog-mediated human rabies through their "Zero by 30" campaign. This review examines the difficulties and tactics used by veterinarians to accomplish this. It looks at One Health strategies, surveillance, wildlife control, and mass dog vaccination, pointing out regional gaps and achievements. Herd immunity requires 70% coverage for mass dog vaccination, which is effective but erratic because of community and logistical obstacles. Rabies has been reduced in Europe thanks to wildlife vaccination, but it is not as widely used in Africa. Due to a lack of diagnostic tools, surveillance is crucial but inadequate in Asia and Africa. Despite lacking funding, One Health coordination improves outcomes. While Africa and Asia face delays due to poverty, conflict, and limited access to vaccines, Latin America is on the verge of eradication. Scaling vaccination, enhancing diagnostics, and fortifying One Health policies are among the recommendations. Cost-effective tactics and community involvement are the main areas of research need. To close the funding and policy gaps and reach the 2030 goal, veterinary leadership is essential.

INTRODUCTION

An estimated 59,000 people die from rabies each year, mostly in Africa and Asia, and 3.7 million disability-adjusted life years (DALYs) are lost as a result of this zoonotic viral disease, which has a devastating global impact. The financial cost is equally high, surpassing $8.6 billion annually as a result of livestock losses, lost productivity, and post-exposure prophylaxis (PEP) expenses (1). In rural areas with limited resources, 40% of deaths occur in children under the age of 15, frequently as a result of dog bites. 99% of human cases are transmitted by domestic dogs, making them the main reservoir (2). This highlights the critical role that veterinary interventions play in interrupting the cycle of transmission (3). In order to eradicate dog-mediated human rabies deaths by 2030, the World Health Organization (WHO), World Organization for Animal Health (WOAH, formerly OIE), Food and Agriculture Organization (FAO), and Global Alliance for Rabies Control (GARC) introduced the "Zero by 30" global strategic plan in 2015 (4). This program places a strong emphasis on veterinary-led tactics, such as widespread dog vaccination, improved surveillance, and One Health cooperation between the environmental, animal, and human sectors.

Considerable progress has been made, especially in Latin America, where sustained high-coverage dog vaccination campaigns have reduced human cases by 90% (5). Global efforts, however, have had varying degrees of success; in many endemic areas, only 20–40% of dogs receive yearly vaccinations, which is well below the 70% threshold required for herd immunity (6). The problem is made worse by high-burden regions, especially in Africa and South/Southeast Asia, which struggle with populations of free-roaming dogs, inadequate health systems, and restricted access to PEP (7). Elimination efforts are made more difficult by the economic and social

factors that contribute to rabies, such as poverty and poor dog population control (8). Despite these obstacles, little is known about the veterinary industry's contribution to coordinating field operations with international goals. There is a lack of thorough syntheses of veterinary approaches in the literature since it frequently concentrates on human health outcomes or dispersed regional studies. By methodically assessing the efficacy of veterinary interventions, identifying implementation obstacles, and emphasizing regional disparities, this review closes that gap. It looks at ways to maximize surveillance, One Health coordination, wildlife reservoir management, and mass dog vaccination in order to reach the 2030 goal. In order to offer practical suggestions for veterinary stakeholders, it also looks at policy and research gaps, such as sustainable financing and socio-behavioral barriers. In order to help the international veterinary community accelerate the transition to a world free of rabies, this review synthesizes data from 70 studies conducted between 2000 and 2025 (9).

METHODS

To assess veterinary strategies for rabies elimination, this narrative review compiles evidence from peer-reviewed publications, as well as reports from the WHO, WOAH, and FAO, and grey literature published between 2000 and 2025. Using search terms such as "rabies control," "dog vaccination," "wildlife rabies," and "One Health," literature was compiled from databases including PubMed, Scopus, Web of Science, and CAB Abstracts. Studies addressing veterinary interventions, such as oral vaccination for wildlife, mass dog vaccination, population control, and surveillance, with results like vaccination coverage, case reduction, or implementation difficulties, were the main focus of the selection. Excluded were studies without primary data or unrelated to veterinary roles. With a focus on useful information for veterinarians and policymakers, data on intervention types, regional outcomes, costs (in USD), and barriers were extracted. Study design, sample size, and relevance to the "Zero by 30" goal were taken into consideration when informally evaluating quality, giving field-based evidence and global health reports priority. The review provides a thorough overview without the strict framework of a systematic review by synthesizing findings thematically, covering topics such as surveillance systems, vaccination strategies, and One Health coordination. This strategy highlights both achievements and ongoing gaps in rabies control efforts while guaranteeing accessibility for stakeholders seeking to match field practices with global elimination targets.

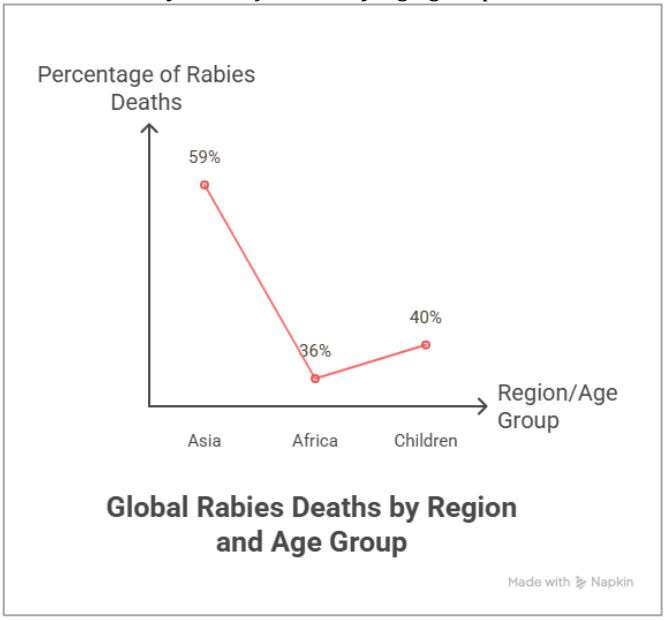
GLOBAL EPIDEMIOLOGY & BURDEN

About 59,000 people die from rabies each year, with 95% of those deaths taking place in Asia (59%) and Africa (36%), making it a serious public health concern as illustrated in **figure 1.0** (1). Forty percent of deaths are in children under the age of fifteen, frequently from dog bites in rural areas where post-exposure prophylaxis (PEP), which costs between forty and one hundred dollars per course, is hard to come by. 99% of human cases are spread by domestic dogs, but foxes, jackals, and raccoons are important wildlife reservoirs in North America and Europe (7). Transmission is influenced by socioeconomic factors, such as poverty and high dog population turnover (3–20% per year), especially in places where the human-to-dog ratio is 10–20:1 (8).

With $500 million from livestock losses in pastoralist communities and $6 billion from PEP and productivity losses in Africa and Asia, the annual economic burden is significant, coming to $8.6 billion. Human deaths have decreased by 15–20% in parts of Asia and Latin America since the "Zero by 30" campaign began in 2015 as a result of increased dog vaccination coverage; however, Africa has not made as much progress because of conflict, inadequate health systems, and underreporting, with only 10% of cases being laboratory-confirmed (9), (10). Dog populations are fragmented by urbanization, which raises the risk of spillover, and vector ranges may be expanded by climate change, which would make control efforts more difficult. Although gaps in data collection and resource allocation continue to be major barriers, veterinary-led interventions particularly mass vaccination and surveillance are essential to lowering this burden and attaining global elimination (11).

Figure 1

Global Mortality Rate of Rabies by Age group



VETERINARY APPROACHES TO RABIES ELIMINATION

Mass Dog Vaccination

The mainstay of rabies eradication is mass dog vaccination, which must be administered 70% of the time in order to produce herd immunity and lower the reproductive number (R0) below 1. Delivery strategies include catch-vaccinate-release for dogs that roam freely, door-to-door campaigns in rural areas (70–90%), and central-point vaccination in urban areas (60–80% coverage) (12). Effective campaigns, such as the one in Mexico, which has achieved 80% coverage and a 90% reduction in human cases since the 1990s, rely on pre-vaccination dog censuses, community engagement through local leaders, and strong cold-chain logistics (9). Due to high numbers of free-roaming dogs, a lack of funding ($1–5 per dog), and a lack of trust in the community, African nations like Tanzania struggle with

20–60% coverage, with 20–30% of dogs being refused (13). Thermostable vaccines improve access in remote locations with erratic electricity by reducing waste by 50% and maintaining efficacy without continuous refrigeration (14). Accurate coverage is ensured by monitoring using mark-recapture surveys and post-vaccination serology; however, since immunity wanes after 1-2 years, maintaining yearly campaigns is essential to preventing resurgence (15). By dispelling myths regarding the safety of vaccinations, community education programs like school-based initiatives in India increase participation by 40% (16). Although adoption is low in Africa due to a lack of digital infrastructure, mobile apps that track vaccinated dogs in real-time improve campaign efficiency. In order to sustain coverage above the 70% threshold, scaling up necessitates overcoming logistical obstacles, obtaining long-term funding, and fostering community trust (17).

Wildlife Vaccination and Reservoir Management

With a 70–90% seroprevalence and a 99% reduction in cases since 2013, oral rabies vaccination (ORV) employing recombinant vaccine baits has eradicated fox rabies in Europe (7). Targeting wildlife reservoirs such as foxes and raccoons, baits are dispersed either manually or aerially throughout forests. ORV trials for mongooses and jackals in Africa demonstrate 50% uptake, but they face obstacles such as high costs ($10–20/km2) and the possibility of bait consumption by non-target species (18). To avoid spillover, integration with dog vaccination is essential in mixed-reservoir areas such as Ethiopia (8). Bait placement is optimized by ecological modeling, but scale-up in low-resource environments is hampered by a lack of resources and experience (19). As in Eastern Europe, cross-border coordination keeps the region rabies-free by preventing reintroduction (20). Investment in regional bait production and distribution safety training are necessary for ORV expansion in Africa (21).

Dog Population Management & Humane Control

Because sterilization programs do not directly stop the spread of rabies, they are less effective than vaccination in controlling the disease, although they do reduce the number of free-roaming dogs by 20–40% (14). By combining vaccination and sterilization, India's Animal Birth Control model increases community acceptance by 30% through education and shelters (16). Humane alternatives are required due to ethical concerns, as culling is prohibited in 50% of countries; however, the expense of these alternatives, which range from $50 to $100 per animal, is a barrier (19). By combining vaccination and sterilization, Mexico's integrated approach decreased cases by 70% (22). It takes consistent work to keep the population under control when there is a high dog turnover rate (10–20% per year) (23). By enlisting local volunteers, community-led programs, such as those in Thailand, improve compliance (24).

Veterinary-led Surveillance & Diagnostics

70% of cases are detected by surveillance systems that are optimized, including passive reporting and active case detection such as integrated bite case management (IBCM) (25). 90% accuracy is possible with diagnostic tools like direct rapid immunohistochemical tests (dRIT); however, sensitivity is limited by Africa's limited lab capacity, with only 20% of labs being equipped (26). By mapping transmission chains, genomic sequencing improves outbreak tracing, but only 20% of African labs are capable of doing so (27). 80% of outbreaks are traced by integrated human-animal surveillance, as in South Africa, but it is underutilized because of a lack of funding and inadequate training. Investing in regional lab networks and portable testing kits is necessary to strengthen diagnostics (28).

Post-exposure Management & PEP Interface

By using 10-day animal observation for veterinary confirmation, unnecessary PEP use is reduced by 30%, saving $40–100 per case (3). Although it has little effect on human transmission, livestock vaccination safeguards financial resources in pastoralist communities (7). By coordinating bite assessments, cooperation with human health sectors, as in Thailand, guarantees effective PEP delivery and lowers costs by 20% (11). To maximize the use of PEP, especially in rural areas with limited access, veterinary training in bite investigation is essential (29). By promoting timely reporting, community awareness initiatives further lower the demand for PEP (30).

One Health & Intersectoral Coordination

Through coordinated human-animal health initiatives, One Health frameworks, such as Zambia's national taskforces, increase compliance by 40% (30). School-based community education raises awareness by 50%, but scalability is limited by a lack of funding (16). When used, FAO/WHO pilot programs show that integrated surveillance is effective, detecting 80% of cases (31). To align veterinary and public health objectives, institutionalizing One Health necessitates cross-sectoral training and policy mandates (32). ASEAN and other regional taskforces improve coordination, but they require long-term funding (33).

Legislation, Policy, Financing & Governance

By requiring owner registration, mandatory vaccination laws, like the one in Serbia, attain 70% compliance. 60% of campaign expenses are paid for by donors, but in nations like Nigeria, shifts to domestic funding are unsuccessful because of financial limitations (31). Through shared surveillance, cross-border agreements, such as ASEAN's, reduce spillover by 30% (33). Enforcement is weakened by weak governance in Africa, where only 20% of nations have strong policies. Public-private partnerships and national rabies control plans are necessary for strengthening governance (34).

Cold Chain, Supply Chain & Vaccine Types

Nobivac and other inactivated vaccines are widely used, but thermostable alternatives improve access in remote locations by reducing waste by 50%. Twenty percent of campaigns experience cold-chain failures, which calls for solar-powered storage and vial monitors (3). The potency of the vaccine must be greater than 2.5 IU/dose, and quality control is essential to avoid failures. As demonstrated in India, producing vaccines locally lowers costs by 30% (35).

Capacity Building and Workforce Development

Because there is only one veterinarian for every 50,000 dogs in Africa, paraveterinary workers must be trained through three-month programs. To scale interventions,

ORV delivery and community engagement skills are essential (36). 500 workers are trained annually by FAO/WOAH courses, but growth is required to reach 2030 targets (37). As in Tanzania, community-based training increases campaign reach by 40% by empowering local volunteers (38).

MONITORING, EVALUATION, METRICS & MODELLING

Indicators such as human exposures, confirmed animal cases, and vaccination coverage (70% target) are used for monitoring. For WOAH certification, there must be no cases for two years, backed by sensitive surveillance such as integrated bite case management (IBCM), which increases detection by 60%. According to mathematical models, rabies could be eradicated by 2030 with consistent 70% coverage, at a global cost of $6.3 billion (1). Due to infrastructure deficiencies, only 10% of African campaigns use digital tools, such as smartphone apps for real-time reporting, which improve accuracy. By involving locals, community-based monitoring, like that used in Tanzania, improves reporting accuracy by 50% (39). Sensitivity analyses emphasize that in order to validate progress, especially in high-burden regions with underreporting, robust data collection is necessary (40). To ensure that elimination strategies are informed by real-time data, scaling up monitoring necessitates training and investment in digital platforms (41).

REGIONAL PERSPECTIVES: SUCCESSES AND PERSISTENT GAPS

Africa

36% of rabies deaths worldwide occur in Africa (21,000 per year), primarily due to low vaccination rates (30%) and campaigns that disrupt peace. Ethiopia's community-led programs reduced cases by 40% and reached 60% coverage in urban areas, but rural areas lag behind because of free-roaming dogs and a lack of funding ($1–3 per dog) (42). As demonstrated in Nigeria, where underreporting causes estimates to be inflated by 80%, surveillance is hampered by a weak diagnostic capacity, with only 10% of cases being lab-confirmed (43). Only 20% of dogs in conflict areas, such as South Sudan, are vaccinated, creating logistical challenges (44). Similar to East Africa, cross-border coordination is essential to preventing reintroduction, but it is constrained by differences in resources (45). Achieving the 2030 target requires securing domestic funding and strengthening lab networks (46).

South & Southeast Asia

Due to low coverage (20–40%) and high dog density (20–50/km2), South and Southeast Asia are responsible for 59% of rabies deaths (35,000 per year) (43). Through community involvement and door-to-door vaccination, Indonesia's Flores campaign reduced cases by 70% and reached 80% coverage (47). India's progress is hampered by a high dog turnover rate of 15% per year and a prevalence of fake vaccines of 10% (48). As demonstrated by Bhutan's educational initiatives, targeted education is necessary to address community mistrust, which has a 30% refusal rate in rural areas (24). While regional collaboration, such as the ASEAN taskforce, improves surveillance, scaling up requires funding (49). It is essential to raise public awareness and improve vaccine quality (47).

Latin America

Using Mexico's centralized campaigns as a model, Latin America has achieved consistent 80% vaccination coverage, resulting in a 90% reduction in human cases (9). Although improvements are maintained through community education and surveillance, including bite reporting systems, border areas like Mexico-Guatemala run the risk of reintroduction because of stray dog movement (50). With government funding, costs ($2–5 per dog) can be controlled, but access in rural areas is still difficult. By ensuring cross-border coordination, regional agreements such as PAHO's reduce spillover by 40%. To achieve elimination, ongoing investment in vaccination and surveillance is required (51).

Europe & North America

With the help of robust veterinary systems, fox rabies cases in Europe have decreased by 99% since 2013 thanks to wildlife oral vaccination (7). In order to maintain low case numbers, the United States employs ORV for raccoons (52). Reintroduction from Eastern Europe, where stray dogs are dangerous, is prevented by ongoing surveillance. Maintaining rabies-free status requires consistent funding and cross-border cooperation (53).

Oceania

Using Australia's quarantine system as a model, strict import controls and surveillance are necessary to maintain Oceania's rabies-free status (54). In order to prevent introduction, Pacific islands enforce vigilance through port inspections (55). Compliance is guaranteed by community awareness, but future risks are presented by climate-driven vector expansion (56).

CROSS-CUTTING CHALLENGES & KEY GAPS

Eliminating rabies worldwide is fraught with difficulties. Since only 10% of cases are lab-confirmed, there are significant surveillance gaps, with 80% of cases in Africa being underreported as a result of poor diagnostics and restricted lab access. Underreporting delays response in Nigeria by inflating estimates by 80% (57). 60% of African programs are donor-dependent, and a $3.9 billion funding deficit restricts the scalability of campaigns (58). Myths about vaccine safety, as observed in India, are the root cause of sociocultural barriers, such as the 30% vaccination refusal rates in rural Asia. 10% of vaccine supplies in Asia are counterfeit, which lowers effectiveness and undermines confidence (47). As demonstrated in Kenya, enforcement is hampered by weak governance in Africa, where only 20% of nations have effective rabies policies (55). By dividing dog populations, urbanization raises the risk of spillovers, and modeling studies suggest that climate change may increase the ranges of vectors. Disparities are made worse by unequal access, as 50% of rural and refugee populations do not have PEP (8). Control is made more difficult by gender dynamics, as women are less likely to report bites because of social stigma (59). Logistical obstacles cut coverage to 20% in conflict areas like South Sudan (60). Innovative funding methods like public-private partnerships and community involvement through school programs that raise awareness by 50% are needed to address these. As in

Serbia, compliance is ensured by strengthening governance through national rabies control plans (61). Access could be enhanced by creating portable diagnostics like dRIT and thermostable vaccines. Although it requires funding, cross-border coordination, like that in ASEAN, reduces spillover by 30%. To close gaps and reach "Zero by 30," it is essential to incorporate One Health frameworks and use digital tools for real-time surveillance (62).

POLICY AND PRACTICE RECOMMENDATIONS

Short-term (2025–2027): Prioritize high-burden regions such as Africa and use door-to-door and catch-vaccinate-release methods to increase mass dog vaccination to 70% coverage. In South Africa, integrated bite case management (IBCM) was piloted to increase detection by 60% (63). To address shortages, provide paraveterinary workers with training (58).

Mid-term (2027–2028): To improve coordination, institutionalize One Health platforms through national policies, as Zambia has done. Reduce reliance on donors by securing long-term funding through global health funds such as Gavi. Create vaccines that are thermostable to cut waste in half (64).

Long-term (2030): With strong surveillance, maintain zero cases for two years to obtain WOAH certification. To stop reintroduction, fortify cross-border agreements such as those of ASEAN (65). Cost-effectiveness studies and community engagement tactics to increase compliance by 40% are among the research priorities. Progress tracking will be ensured by expanding digital tools for real-time monitoring (17).

Future Directions & Research Gaps

Since current indicators vary greatly, one of the main research gaps is the need for standardized global metrics to compare program effectiveness across regions. To model sustainable financing in low-resource environments, especially in Africa, cost-effectiveness studies are required. Since the effects of sterilization are unknown, randomized studies contrasting vaccination-only approaches with dog population management could measure synergies (66). Only 20% of African labs have adopted genomic surveillance, which uses phylodynamic tools to track transmission chains and improve control. In order to improve vaccination uptake, behavioral studies on community trust could address 30% refusal rates. For remote locations, the development of portable diagnostics such as dRIT and thermostable vaccines is essential (3).

STRENGTHS & LIMITATIONS

This narrative review offers a thorough veterinary viewpoint on the eradication of rabies, combining 70 studies to direct "Zero by 30" initiatives in various geographical areas. It provides useful insights for veterinarians and policymakers by highlighting doable tactics like One Health coordination and mass dog vaccination. Relevance to global stakeholders is ensured by the inclusion of regional case studies, such as the difficulties faced by Africa and the achievements of Mexico (9). Systemic barriers are addressed by concentrating on cross-cutting issues such as funding and governance. However, because unsuccessful programs go unreported, there may be a bias in favor of successful interventions. Precision in comparing results is limited by heterogeneous data from various study designs, which hinder quantitative synthesis (67). Findings may be skewed toward urban successes due to the underrepresentation of low-resource settings, especially conflict zones. Although grey literature helps to mitigate this, relying solely on English-language sources may miss regional insights. To improve equity, future reviews should concentrate on underserved areas and incorporate multilingual sources (68).

CONCLUSION

In order to eradicate 59,000 human deaths annually, "Zero by 30" necessitates strong veterinary leadership in mass dog vaccination, surveillance, and One Health coordination. As evidenced by the 90% case reduction in Latin America, sustained 70% vaccination coverage is essential. However, because of logistical, financial, and sociocultural obstacles, coverage in Africa and Asia is consistently low, ranging from 20 to 40 percent. Expanding genomic surveillance and bolstering diagnostics, such as dRIT, can improve outbreak detection, especially in Africa, where only 20% of labs are outfitted. One Health frameworks, like the one in Zambia, increase compliance by 40%, but they need to be institutionalized through mandates from policy. To close the $3.9 billion gap, sustainable funding, possibly through global health funds, is necessary. To address refusal rates, community engagement through school programs increases awareness by 50%. Reintroduction is avoided through cross-border coordination, as in ASEAN. To address shortages, particularly in Africa, veterinary education and Para veterinary programs are essential. To guarantee fair progress, stakeholders must move quickly to scale interventions, implement regulations, and fund studies like thermostable vaccines. With concerted, veterinary-led efforts, it is possible to eradicate rabies worldwide by 2030.

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