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Challenges in the planning and implementation of mass rabies vaccination campaigns in dogs: A one health perspective

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Abstract

Rabies remains one of the most important neglected zoonotic diseases, with dog-mediated transmission responsible for the great majority of human rabies deaths. Mass dog vaccination (MDV) is the principal intervention for interrupting transmission at its animal source, but the effectiveness of vaccination campaigns depends on more than vaccine availability. Campaigns may fail to achieve sustained population protection because of inaccurate dog-population estimates, inadequate microplanning, inappropriate vaccination strategies, geographical barriers, insufficiently trained personnel, vaccine and cold-chain constraints, weak communication, poor monitoring, financial limitations and fragmented institutional coordination. This review critically examines the major operational and epidemiological challenges affecting MDV programmes and considers them within a One Health framework. Evidence indicates that campaign completeness, accessibility of dogs, geographical distribution of vaccination points, community participation and the continuity of vaccination activities can be as important as the nominal number of vaccine doses administered. Emerging approaches, including geographic information system-assisted microplanning, digital vaccination records, community-based continuous vaccination, improved post-campaign coverage surveys and oral rabies vaccination of dogs, may complement conventional fixed-point and door-to-door approaches. Sustainable progress additionally requires integration of animal vaccination with human post-exposure prophylaxis, laboratory-based surveillance, responsible dog population management, risk communication and coordinated financing. Successful rabies elimination therefore requires a shift from short-term vaccination drives toward evidence-based, geographically targeted and continuously monitored programmes implemented through coordinated One Health systems.

Keywords: Rabies; Dogs; Mass vaccination; One Health; Vaccination coverage

1. Introduction

Rabies is a fatal zoonotic disease caused by rabies virus and related lyssaviruses and remains a major public-health problem in many parts of Asia and Africa. Although rabies is preventable through timely post-exposure prophylaxis (PEP) and can be controlled at its animal source through vaccination, approximately 59,000 human deaths are estimated to occur annually, with the majority associated with dog-mediated transmission in endemic regions (Hampson *et al.*, 2015; World Health Organization *et al.*, 2018). The disease is therefore unusual among major zoonoses because its elimination is technically feasible but remains operationally difficult in many settings.

Dog vaccination is the cornerstone of dog-mediated rabies elimination. Mathematical and field studies have demonstrated that sufficiently high and sustained vaccination coverage can interrupt transmission within dog populations (Coleman & Dye, 1996; Hampson *et al.*, 2009; Lembo *et al.*, 2010; Zinsstag *et al.*, 2009). A vaccination coverage level of approximately 70% is widely used as an operational target; however, achieving a nominal percentage alone does not necessarily guarantee effective control. Coverage must be sufficiently homogeneous across areas where dogs and rabies transmission are concentrated, and vaccination programmes must be repeated at appropriate intervals to compensate for demographic

turnover and waning immunity (Coleman & Dye, 1996; Lembo *et al.*, 2010; Rupprecht *et al.*, 2002).

The challenge is particularly pronounced in low- and middle-income settings where dog populations may be poorly enumerated, ownership patterns vary considerably, veterinary infrastructure is limited and free-roaming dogs are difficult to access. Social factors also influence campaign participation. Distance to vaccination points, inadequate publicity, inconvenient vaccination schedules, misconceptions regarding vaccines, fear of dog handling, vaccination fees and limited trust in authorities have all been associated with reduced participation in vaccination campaigns (Akankwatsa *et al.*, 2025; Barbosa Costa *et al.*, 2020; Bardosh *et al.*, 2014; Chazya *et al.*, 2025; Duamor *et al.*, 2022; Kayali *et al.*, 2003; Mazeri *et al.*, 2018).

Recent studies have further demonstrated that the effectiveness of MDV programmes is influenced by the spatial organisation of campaigns. Geographical heterogeneity in dog density, settlement patterns, roads, terrain, poverty and access to vaccination sites can produce substantial variation in campaign completeness even when overall programme coverage appears satisfactory (Lembo *et al.*, 2010; Sambo *et al.*, 2024; Scott & Nel, 2021; Wallace *et al.*, 2017a). Experience from integrated programmes, including the One Health intervention implemented in Goa, India, illustrates the potential value of combining mass vaccination with surveillance, community engagement, human health interventions and digital spatial management (Gibson *et al.*, 2022).

Consequently, the principal challenge is no longer simply whether dogs can be vaccinated, but whether vaccination programmes can consistently identify the target population, reach an adequate proportion of dogs, maintain vaccine quality, engage communities, document coverage and coordinate veterinary, public-health and administrative systems.

This review critically examines these challenges and proposes an integrated implementation framework for improving MDV programmes, with particular emphasis on operational planning, accessibility, community participation, monitoring, sustainability and One Health coordination.

2. Scope and Literature Approach

This article is a narrative and critical review of evidence concerning the planning, implementation and evaluation of MDV campaigns for dog-mediated rabies control. Relevant literature was considered from peer-reviewed veterinary, public-health and infectious-disease publications together with guidance and technical documents from international organisations involved in rabies control.

The literature was identified using combinations of the terms rabies, canine rabies, mass dog vaccination, dog vaccination coverage, vaccination campaigns, campaign barriers, dog population estimation, community participation, microplanning, One Health, rabies elimination, oral vaccination, surveillance and implementation science. Particular attention was given to studies evaluating real-world campaign performance, geographical access, community participation, vaccination coverage and programme costs. International guidance from the World Health Organization (WHO), World Organisation for Animal Health (WOAH) and the United Against Rabies collaboration was also considered (WHO *et al.*, 2018; WOAH, n.d.-a; WOAH, n.d.-b).

The purpose was not to conduct a formal systematic review or meta-analysis but to synthesise operational evidence and identify recurrent barriers that can affect the effectiveness and sustainability of MDV programmes.

3. Epidemiological Rationale for Mass Dog Vaccination

Dog-mediated rabies represents a particularly suitable target for source-directed disease control because domestic dogs constitute the principal reservoir and transmitter of human rabies in many endemic regions (Fooks *et al.*, 2014; Hampson *et al.*, 2015; Knobel *et al.*, 2005; WHO *et al.*, 2018; WHO *et al.*, 2018). Unlike wildlife-mediated rabies cycles, canine rabies can be controlled through repeated vaccination of the domestic dog population.

The epidemiological basis of MDV is supported by studies demonstrating that high vaccination coverage reduces the effective transmission potential of rabies within dog populations (Coleman & Dye, 1996; Hampson *et al.*, 2009; Lembo *et al.*, 2010; Zinsstag *et al.*, 2009). Coleman and Dye proposed that approximately 70% vaccination coverage could prevent sustained transmission under defined epidemiological conditions (Coleman & Dye, 1996). Subsequent field studies have demonstrated that vaccination campaigns reaching high coverage can substantially reduce canine rabies incidence and human exposure (Cleaveland *et al.*, 2006; Gibson *et al.*, 2022;

Lembo *et al.*, 2010; Tenzin *et al.*, 2011; Townsend *et al.*, 2013).

However, vaccination coverage should not be interpreted as a single national or administrative average. A programme reporting 70% coverage at district level may still leave clusters of susceptible dogs if vaccination is concentrated around accessible settlements while peripheral areas remain poorly covered. Spatial heterogeneity can therefore permit continued transmission (Lembo *et al.*, 2010; Sambo *et al.*, 2024; Scott & Nel, 2021; Wallace *et al.*, 2017a).

Dog population turnover presents another challenge. Puppies entering the population, deaths, migration and changes in ownership continuously alter the susceptible population. Studies of dog demography have demonstrated that campaign performance is influenced by the age structure, survival and recruitment of dogs (Belsare *et al.*, 2013; Davlin *et al.*, 2012; Morters *et al.*, 2014). Consequently, a single campaign cannot provide permanent population immunity.

The epidemiological objective should therefore be viewed as sustained, geographically distributed vaccination sufficient to maintain population-level immunity over successive campaign cycles, rather than as a one-time achievement of a numerical coverage target.

4. Inadequate Campaign Planning and Microplanning

Effective MDV begins before vaccination teams enter the field. Microplanning should translate a broad programme objective into operational plans specifying target populations, vaccination teams, routes, vaccination sites, equipment, vaccine requirements, communication activities, supervision and monitoring arrangements.

Inadequate planning can result in insufficient vaccine quantities, poorly located vaccination points, uneven team deployment, duplication of effort in accessible areas and inadequate attention to remote settlements. Implementation research has identified unclear responsibilities, insufficient materials, short campaign periods, weak coordination and inadequate evaluation as recurrent barriers (Castillo-Neyra *et al.*, 2025; Duamor *et al.*, 2026; Lim *et al.*, 2022).

A campaign should therefore be based on a geographically explicit operational plan. Areas should be divided into manageable vaccination units, with estimated dog populations, human settlements, roads, terrain, veterinary facilities and previous vaccination performance incorporated into planning.

GIS-based approaches can improve resource allocation by identifying poorly served areas and helping teams optimise routes. Recent field evidence indicates that environmental and socioeconomic variables can influence vaccination completeness and coverage, demonstrating the value of spatially informed microplanning (Sambo *et al.*, 2024).

Microplanning should also distinguish between urban, peri-urban and rural areas. High-density urban populations may permit greater use of fixed vaccination points, whereas dispersed rural settlements may require mobile or door-to-door teams.

5. Inaccurate Estimation of the Dog Population

The denominator used to calculate vaccination coverage is one of the most important determinants of programme interpretation. If the dog population is underestimated, reported coverage may be artificially high; if it is substantially overestimated, programme performance may appear poor despite adequate vaccination.

Reliable dog population estimation is difficult because free-roaming dogs may be unregistered, ownership status may be unclear and populations can change rapidly. Dog-to-human ratios also vary between communities and cannot necessarily be transferred from one geographic setting to another (Davlin *et al.*, 2012; Gsell *et al.*, 2012; Kitala *et al.*, 2000; Matter *et al.*, 2000).

Household surveys, capture-recapture approaches, photographic identification, direct enumeration and statistical modelling have all been used to estimate dog populations. Each approach has advantages and limitations. For routine programmes, practical estimates should ideally be refined using vaccination records, previous campaign data and post-campaign surveys.

Population estimates should also incorporate demographic turnover. Puppies and newly introduced dogs represent a continuing susceptible population. Puppies may be incompletely represented during surveys and may subsequently become susceptible after reaching the vaccination-eligible age (Belsare *et al.*, 2013; Morters *et al.*, 2014).

A useful approach is therefore to establish a baseline dog population estimate and update it periodically rather than treating the denominator as fixed.

6. Selection of an Appropriate Vaccination-Delivery Strategy

No single vaccination strategy is appropriate for every setting. Common approaches include fixed-point vaccination, temporary central-point vaccination, door-to-door vaccination, mobile teams and combinations of these methods.

Fixed-point vaccination can be efficient where communities are geographically concentrated and owners can readily reach vaccination sites. However, studies from several endemic settings have demonstrated that distance and accessibility can substantially reduce attendance at static vaccination points (Akankwatsa *et al.*, 2025; Chazya *et al.*, 2025; Lugelo *et al.*, 2022; Mazeri *et al.*, 2018). Door-to-door vaccination improves accessibility and can reach dogs whose owners may not attend central sites. It may nevertheless require greater human resources, transportation and supervision and can become difficult in densely populated areas or settlements with restricted access.

A hybrid strategy is frequently more practical. Fixed sites may serve densely populated areas, while mobile or door-to-door teams can target peripheral settlements and locations with historically low coverage. The choice of strategy should be based on local dog ecology, settlement distribution, road accessibility, human population density, community behaviour, available workforce and programme resources.

7. Geographical Accessibility and Campaign Completeness

Geographical access is increasingly recognised as a major determinant of vaccination success. Dogs living close to vaccination facilities may have substantially greater access to vaccination than dogs in remote or poorly connected settlements.

Recent field research demonstrated that land cover, elevation, poverty, residence patterns and other geographic characteristics can influence the completeness and coverage of MDV campaigns (Sambo *et al.*, 2024). Similarly, studies from Uganda, Zambia, Malawi and Haiti identified distance and accessibility as important barriers to participation (Akankwatsa *et al.*, 2025; Barbosa Costa *et al.*, 2020; Chazya *et al.*, 2025; Mazeri *et al.*, 2018).

Campaign maps should therefore identify:

1. Settlements and neighbourhoods;
2. Estimated dog populations;
3. Previous vaccination coverage;
4. Vaccination points;
5. Roads and transportation routes;
6. Remote or difficult-to-access areas;
7. High-risk locations; and
8. Areas with repeated low coverage.

Vaccination teams should be allocated according to workload and geography rather than simply according to administrative boundaries.An important concept is campaign completeness. A programme may administer thousands of doses while leaving entire settlements unvisited. Monitoring should therefore ask not only “How many dogs were vaccinated?” but also “Which areas were reached, which were missed and why?”

8. Human Resources, Dog Handling and Occupational Safety

The availability of trained personnel directly influences the quality and safety of MDV programmes. Teams require appropriate knowledge of dog behaviour, safe restraint, vaccination technique, cold-chain procedures, documentation and community communication.

Dog handling can be particularly difficult where free-roaming or aggressive dogs are common. Inadequate training may lead to failed vaccinations, unnecessary occupational injuries and reduced public confidence.

The use of trained community-based vaccinators may help expand programme capacity. A scoping review found that appropriately trained lay vaccinators can contribute to animal vaccination programmes when adequate supervision, training and quality-control systems are provided (Duamor *et al.*, 2021). Vaccination teams should be equipped with appropriate personal protective equipment, dog-catching equipment where required, first-aid resources and clear procedures for occupational exposure. Rabies exposure protocols should be established before campaigns begin.The objective should not simply be to increase the number of vaccinators, but to create a competent, supervised and appropriately distributed workforce.

9. Vaccine Procurement, Supply and Cold-Chain Management

High-quality rabies vaccines are essential for effective disease control. Procurement systems should ensure adequate quantities of WHO/WOAH-appropriate veterinary rabies vaccines, with sufficient reserve stocks to compensate for wastage, damaged vials and unexpected increases in demand.

Cold-chain management is particularly important for vaccines requiring temperature-controlled storage. Breaks in the cold chain may compromise vaccine quality even when the nominal number of doses administered is high. Vaccine stability is product-specific: experimental work on one inactivated canine rabies vaccine found that its antibody response

was maintained after controlled storage at elevated temperatures; this finding should not be generalised to other products or used to override the manufacturer's storage instructions (Lankester *et al.*, 2016).

Operational planning should include:

- Vaccine forecasting;
- Procurement lead time;
- Batch documentation;
- Temperature monitoring;
- Cold-chain transport;
- Secure storage;
- Appropriate reconstitution and handling;
- Wastage monitoring; and
- Contingency stocks.

Campaign records should permit traceability of vaccine batches. Vaccination teams should also record doses administered rather than relying solely on doses issued.

10. Community Engagement, Communication and Trust

Community participation is one of the most important determinants of campaign success. Vaccination is ultimately dependent on owners or community members presenting, restraining or permitting access to dogs.

Barriers may include limited awareness, misconceptions about rabies or vaccines, fear of adverse reactions, concerns about dog handling, distrust of authorities, inconvenience, vaccination charges and inadequate publicity (Akankwatsa *et al.*, 2025; Barbosa Costa *et al.*, 2020; Bardosh *et al.*, 2014; Duamor *et al.*, 2022; Kaare *et al.*, 2009; Kayali *et al.*, 2003; Sambo *et al.*, 2014).

Communication should therefore begin before vaccination starts. Campaign messages should clearly explain:

- Why dogs should be vaccinated;
- Where vaccination will occur;
- When teams will visit;
- Whether vaccination is free;
- Which dogs are eligible;
- Whether certificates or vaccination tags will be provided;
- What owners should do if a dog is missed; and
- Where suspected rabies cases should be reported.

Evidence from Tanzania indicates that community engagement can improve participation by creating a sense of collective responsibility for vaccination (Duamor *et al.*, 2022). Community leaders, local veterinarians, schools, health workers, municipal authorities and animal welfare organisations can serve as communication partners. Communication should not be limited to posters. Radio, social media, community meetings, local-language announcements, schools and interpersonal communication may be combined according to the target population.

11. On-Site Counselling and Service Navigation

A frequently overlooked component of vaccination campaigns is the availability of immediate information and counselling for owners.

A vaccination point can function as an entry point for broader rabies prevention by providing information about bite management, PEP, vaccination schedules, responsible dog ownership and procedures for reporting suspected rabies.

Owners may also require clarification when a dog is sick, pregnant, very young, previously vaccinated or difficult to restrain. Clear protocols can reduce confusion and improve confidence in the programme.

Rather than establishing expensive permanent counselling centres in every locality, programmes can provide trained information personnel at major vaccination sites and use mobile communication channels for follow-up.The principle is that vaccination should be accompanied by accessible information, rather than treated as an isolated technical procedure.

12. Timing, Seasonality and Environmental Conditions

Campaign timing can affect participation and operational efficiency. Rainfall, extreme temperatures, flooding, agricultural activity, festivals, school schedules and local work patterns can influence the ability of communities and vaccination teams to participate.

Seasonal dog movement and breeding patterns may also influence the susceptible population. Campaign scheduling should therefore consider both epidemiological and operational factors.

A short campaign may be attractive administratively but can create access problems when large populations must be vaccinated within a narrow period. Evidence from implementation studies suggests that inadequate campaign duration can contribute to incomplete coverage (Castillo-Neyra *et al.*, 2025; Duamor *et al.*, 2026; Lim *et al.*, 2022).Where feasible, vaccination programmes should provide sufficient operating days and flexible hours, including early morning or late afternoon

activities in communities where owners are less available during conventional working hours. Weather contingency plans should be incorporated into campaign micro plans rather than treated as unexpected events.

13. Monitoring Vaccination Coverage

Vaccination coverage is meaningful only when the denominator is credible and vaccination records are geographically traceable.

Programme monitoring should distinguish between:

- **Administrative coverage:** the proportion vaccinated according to programme records.
- **Survey-estimated coverage:** the proportion vaccinated according to independent field assessment.
- **Geographical completeness:** the proportion of target areas actually reached.

These indicators answer different questions and should not be treated as interchangeable.

Independent post-campaign surveys are particularly important because administrative data may overestimate coverage if denominators are inaccurate or duplicate vaccinations occur.

A useful monitoring framework should include:

- Number of dogs vaccinated;
- Estimated dog population;
- Proportion of target settlements reached;
- Proportion of vaccination points operational;
- Vaccine wastage;
- Adverse events;
- Occupational exposures;
- Number of missed dogs;
- Geographic distribution of vaccination;
- Percentage of puppies vaccinated;
- Campaign expenditure; and
- Human and animal rabies cases before and after intervention.

Digital systems can facilitate real-time reporting. The Goa programme demonstrated the value of smartphone-based spatial allocation and monitoring within an integrated rabies-control programme (Gibson *et al.*, 2022).

14. Financial and Infrastructure Constraints

Financial limitations influence almost every component of MDV, including vaccines, transport, cold-chain infrastructure, personnel, communication, data management and post-campaign evaluation.

Importantly, the cost of vaccination should not be considered independently from the costs of rabies exposure and PEP. Economic evaluations have demonstrated that dog vaccination can be an economically attractive component of rabies control, particularly when the costs of human PEP and rabies deaths are incorporated (Kayali *et al.*, 2006; Lembo *et al.*, 2010; Mindekem *et al.*, 2017; Wera *et al.*, 2017; Zinsstag *et al.*, 2009).

Fee-based vaccination may recover some programme costs but can reduce participation among economically disadvantaged households. Evidence from African programmes suggests that vaccination fees can influence participation, although the magnitude of the effect varies by setting (Jibat *et al.*, 2015; Kayali *et al.*, 2003).

Sustainable programmes should therefore avoid reliance on short-term campaign financing alone. Budgeting should cover the complete intervention cycle, including planning, implementation, supervision, evaluation and subsequent campaign rounds.A sustainable financial model may combine government resources, municipal budgets, public-health programmes, international support and appropriately regulated partnerships.

15. One Health Coordination as the Foundation of Sustainable Rabies Control

Rabies control cannot be achieved by veterinary services acting independently of the human-health sector. A bite from a rabid dog creates a direct interface between animal health, human health, laboratory diagnosis and community behaviour.

An effective One Health system should integrate:

i. Animal vaccination;
ii. Animal rabies surveillance;
iii. Human bite surveillance;
iv. Pep access and reporting;
v. Laboratory diagnosis;
vi. Community communication;
vii. Dog population management;
viii. Data sharing; and
ix. Joint programme evaluation.

The Goa experience provides an important example of integrated intervention, combining large-scale dog vaccination, surveillance, community engagement and human-health activities and demonstrating substantial reductions in canine rabies and human rabies during programme implementation (Gibson *et al.*, 2022).

One Health coordination should also occur at operational levels. District veterinary officers, municipal authorities, public-health officials, laboratories and community organisations

should have clearly defined responsibilities. A One Health approach is therefore not simply a conceptual framework; it should be reflected in budgets, reporting systems, surveillance protocols and accountability mechanisms.

16. Surveillance and Laboratory Support

Vaccination campaigns should operate alongside effective rabies surveillance. Surveillance data can identify areas where transmission persists and can guide subsequent vaccination activities.

Animal surveillance should include investigation of suspected rabies cases, laboratory confirmation where feasible, geographic recording of cases and integration with human bite data.

The value of surveillance extends beyond disease confirmation. Spatially linked surveillance data can identify persistent transmission foci and help determine whether vaccination gaps, dog population turnover or other factors are contributing to continued cases.

Recent One Health initiatives in India have highlighted the importance of strengthening animal rabies surveillance and collaboration between veterinary and public-health stakeholders (Mohanty *et al.*, 2026). Laboratory confirmation also supports epidemiological understanding by permitting characterisation of circulating viruses and identification of transmission patterns where appropriate.

17. Dog Population Management and Responsible Ownership

Vaccination remains the principal intervention for preventing dog-mediated rabies, but dog population dynamics influence long-term campaign performance.

Uncontrolled reproduction can rapidly increase the number of susceptible animals. Conversely, indiscriminate dog removal is not an evidence-based substitute for vaccination and may have unintended ecological and social consequences.

Responsible dog ownership, sterilisation programmes where appropriate, registration, identification, vaccination and humane population management can complement MDV.

Population management should therefore be integrated with vaccination rather than replacing it. The objective is to maintain a stable, vaccinated and identifiable dog population capable of being repeatedly reached by veterinary services.

18. Emerging Strategy: Community-Based Continuous Vaccination

Conventional annual or periodic campaigns may leave substantial gaps between vaccination activities. Community-based continuous vaccination has emerged as an alternative or complementary approach.

Continuous approaches attempt to integrate vaccination into routine community and veterinary services rather than concentrating all activity into a short campaign window. Recent implementation research has examined the feasibility of community-based continuous vaccination and highlighted the importance of local participation, workforce organisation and adaptation to community circumstances (Duamor *et al.*, 2026).

Such systems may be particularly useful in areas with high dog population turnover or where annual campaigns repeatedly fail to achieve adequate coverage. However, continuous vaccination requires reliable financing, permanent or semi-permanent service capacity, monitoring systems and mechanisms for identifying newly eligible dogs.

19. Emerging Strategy: Geographic Information Systems and Digital Technologies

Digital technologies provide opportunities to improve campaign planning and monitoring.

GIS can be used to:

- Map dog populations;
- Identify vaccination gaps;
- Optimise team routes;
- Locate vaccination points;
- Monitor campaign progress;
- Identify persistent rabies hotspots; and
- Integrate animal and human surveillance.

Smartphone-based data collection can reduce delays between field activities and programme management. Digital vaccination certificates can also improve individual animal records where infrastructure permits.

However, digital tools should not become a substitute for field capacity. Systems must remain usable under low-connectivity conditions, and data quality, privacy, training and device availability must be considered. Technology should therefore be viewed as an enabling component of programme implementation rather than an independent intervention.

20. Emerging Strategy: Oral Rabies Vaccination of Dogs

Parenteral vaccination remains the principal approach for domestic dogs, but oral rabies vaccination (ORV) has potential as an adjunct in

situations where conventional vaccination is difficult.

Research on oral vaccines has demonstrated the feasibility of immunising dogs through oral delivery, and reviews have examined the potential application of oral vaccination in India and other endemic settings (Cliquet *et al.*, 2007; Prathapan *et al.*, 2025; Yale *et al.*, 2022).

ORV may be particularly relevant for free-roaming dogs that are difficult to capture or safely restrain. However, operational feasibility, vaccine acceptance, bait distribution, cost, regulatory requirements and post-deployment monitoring must be carefully evaluated.ORV should therefore be considered a complementary tool for specific populations or settings, rather than a universal replacement for parenteral vaccination.

21. Implementation Framework for Effective Mass Dog Vaccination

The evidence reviewed suggests that successful MDV requires simultaneous attention to epidemiological, operational, geographic, social and institutional factors.

Table 1. Major barriers to effective mass dog vaccination and potential mitigation strategies

Barrier	Operational consequence	Potential mitigation
Inaccurate dog population estimate	Artificially high or low coverage	Periodic surveys and denominator refinement
Poor microplanning	Uneven team deployment	GIS-assisted microplanning
Fixed-point-only strategy	Exclusion of remote dogs	Hybrid fixed/mobile/door-to-door strategy
Long distance to vaccination site	Reduced participation	More sites and mobile teams
Inadequate publicity	Low owner attendance	Pre-campaign multilingual communication
Short campaign duration	Missed dogs and settlements	Flexible and sufficiently long campaign windows
Inadequate workforce	Low campaign capacity	Training, supervision and community vaccinators
Vaccine supply problems	Interrupted vaccination	Forecasting and buffer stocks
Cold-chain failures	Potential loss of vaccine quality	Temperature monitoring and contingency systems
Poor dog handling	Failed vaccination and injuries	Training and appropriate equipment
Weak monitoring	Overestimation of coverage	Independent post-campaign surveys
Fragmented institutions	Delayed response	One Health coordination mechanism
Insufficient financing	Irregular campaigns	Multi-year programme budgeting
High dog turnover	Declining immunity	Repeated vaccination and puppy coverage
Community misconceptions	Vaccine refusal	Local engagement and risk communication

22. Recommended Core Indicators for Campaign Evaluation

Table 2. Suggested indicators for routine MDV programme monitoring

Domain	Indicator
Population	Estimated total dog population
Vaccination	Number of dogs vaccinated
Coverage	Administrative vaccination coverage
Verification	Independently estimated coverage
Geography	Percentage of target settlements reached
Accessibility	Percentage of identified difficult-access areas covered
Puppies	Proportion of eligible puppies vaccinated
Vaccine	Doses supplied, administered and wasted
Cold chain	Percentage of monitoring records within required temperature range
Workforce	Number of trained and supervised vaccinators
Safety	Dog-bite and occupational-exposure incidents
Community engagement	Number/reach of communication activities
Surveillance	Suspected and laboratory-confirmed animal rabies cases
Human health	Reported dog bites and PEP utilization
Finance	Cost per vaccinated dog
Continuity	Time between successive campaigns
Programme quality	Percentage of missed settlements revisited

23. Towards a More Effective Campaign Model

The evidence supports a transition from the concept of a vaccination campaign as a short event toward a vaccination programme as a continuous cycle.

A robust programme can be organized into six linked stages:

Stage 1 Assess
Estimate dog populations, identify high-risk areas and analyse previous campaign performance.

Stage 2 – Plan
Develop geographically explicit microplans, calculate vaccine and workforce requirements and select appropriate delivery strategies.

Stage 3 – Engage:
Inform communities, involve local leaders and establish mechanisms for reporting missed dogs.

Stage 4 – Vaccinate
Deploy trained teams using a combination of fixed, mobile and door-to-door strategies according to local conditions.

Stage 5 – Verify
Conduct independent post-campaign assessment, identify geographical gaps and analyse vaccination records.

Stage 6 – Adapt
Use surveillance and monitoring data to redesign the subsequent vaccination cycle.

This adaptive model is particularly important because dog populations, human behaviour, infrastructure and disease risk change over time.

24. Critical Gaps in Current Evidence

Although considerable evidence exists regarding MDV, several knowledge gaps remain.

First, many studies measure vaccination coverage without simultaneously measuring geographical completeness. Second, dog population estimates remain uncertain in many endemic areas. Third, the long-term sustainability of continuous vaccination approaches requires further evaluation. Fourth, the comparative cost-effectiveness of different vaccination strategies varies between epidemiological and socioeconomic settings.

There is also a need for more evidence from South Asia, particularly from diverse rural, peri-urban and urban environments in India. Research should increasingly evaluate not only whether vaccination was delivered but why specific communities or geographic areas were missed.

Implementation science provides a useful framework for addressing these questions by examining the interaction between intervention design, context, workforce, community behaviour and health-system capacity. Future research should also examine the integration of digital technologies, oral vaccination, community vaccinators, electronic certificates and combined animal-human surveillance systems.

25. Conclusion

Mass dog vaccination remains the central intervention for controlling and ultimately eliminating dog-mediated human rabies. However, vaccination effectiveness depends on substantially more than the number of vaccine doses administered. Inaccurate population estimates, poor microplanning, inappropriate delivery strategies, geographical inaccessibility, inadequate personnel, vaccine logistics, weak communication, insufficient monitoring, financial limitations and fragmented institutional responsibilities can all reduce programme performance.

The evidence reviewed indicates that sustained and geographically distributed vaccination is more important than achieving a single nominal coverage value. Campaigns should therefore be designed around the characteristics of local dog populations, settlement patterns and community behaviour.

Future programmes should combine conventional vaccination approaches with GIS-assisted planning, independent coverage evaluation, continuous community engagement, digital monitoring, integrated surveillance and appropriately targeted alternative delivery methods. Oral vaccination may complement parenteral approaches where dogs are difficult to access, while community-based continuous vaccination may help address demographic turnover and gaps between campaigns.

Most importantly, rabies elimination requires a functional One Health system in which veterinary services, public-health authorities, laboratories, municipalities, communities and other relevant stakeholders share information and responsibilities. Moving from isolated vaccination drives to continuously monitored, evidence-based and locally adapted programmes offer a more sustainable pathway toward the elimination of dog-mediated human rabies.

Conflict of interest

The authors declare that they have no conflict of interest related to this manuscript.

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