Reviews

Assessing Health System preparedness for dog mediated rabies in South-East Asia Region

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Keywords

Rabies • One Health • Health System Preparedness • Inter-sectoral coordination • Mass Dog Vaccination

Summary

Introduction. *Rabies is one of the major public health challenges in the South-East Asia Region (SEAR), which is home to diverse populations where close human-animal interactions are common, creating a conducive environment for the transmission of dog mediated rabies. The scoping review intended to assess the health system preparedness of WHO South-East Asia Region countries, for dog mediated rabies, focusing on prevention, detection, and control efforts.*
Methods. *The published literature was searched using PubMed, Embase, and Scopus databases, focusing on studies published from January 2013 to November 2023. The inclusion criteria encompass primary studies published in English between January 2013 and November 2023 focusing on health system preparedness for prevention, control, and elimination of dog-mediated rabies in SEAR.*
Results. *A total of 178 studies were reviewed. Over the years, significant improvements were seen among most SEAR countries, but countries like Myanmar and the Democratic People's Republic of Korea, have limited published evidence on health system preparedness for dog-mediated rabies. Most of the countries need to focus on various aspects like vaccine availability, inter-sectoral collaboration, robust rabies surveillance and reporting system for both humans and animals, strengthening of laboratory capacity and responsible dog ownership to be in alignment with the global goal of "Zero by 30" of ending dog mediated human rabies deaths by 2030.*
Conclusion. *Each SEAR country demonstrates distinctive strengths and challenges in the elimination of rabies. However, incorporation of inter-sectoral coordination and strengthening the rabies surveillance system by linking both animal and human contribute to the control efforts in South-East Asia countries.*

Introduction

Globally, rabies is estimated to cause 59,000 deaths per year in over 150 countries and causes economic burden in terms of lost lives, medical expenses, livelihood, and incidental expenses, altogether estimated to account for around US$ 8.6 billion per year [1]. Rabies is a zoonotic disease caused by the rabies virus, which spreads through two epidemiological cycles: an urban cycle and a sylvatic cycle [2]. The urban cycle maintains the infection in the dog population, while the sylvatic cycle sustains it within wildlife. According to the World Health Organisation (WHO), in 99% of human rabies cases, the rabies virus is transmitted to humans by dogs. Dog-mediated rabies is endemic in most South-East Asian countries, and therefore approximately 608 million people are at potential risk of rabies [3, 4]. The incidence of dog-mediated cases and the number of human deaths due to rabies both are higher in Asia as compared to other regions of the world [5, 6]. Rabies presents a persistent threat in South-East Asian countries despite being a vaccine- preventable disease and also having existing guidelines for its prevention and control. Asian and African countries contribute around 99% of human rabies deaths worldwide, among which a significant majority accounts for 60% of these deaths taking place in Asia [6].

According to recent studies, there are reportedly challenges which include close human-animal interactions, inadequate health system preparedness, poor inter-sectoral coordination, insufficient resources, absence of political will, ineffective surveillance system, stock shortage of vaccine, restricted access to modern rabies vaccines and complex interplay of epidemiological factors [7]. To effectively address these challenges, various public health strategies such as public awareness campaigns, vaccination programs, post-exposure prophylaxis (PEP), the mitigation of the risk of rabies transmission in humans, and a robust surveillance system for both humans and animals to gather evidence-based data, need to be incorporated [8, 9]. Essentially, a "Multi-sectoral One Health Approach" is now critical for rabies control by understanding the disease dynamics and its close interactions between humans, animals, and environmental elements [7]. Integration of the One Health approach into rabies

control strategies has proven to be cost-effective, where 2249 disability-adjusted life years (DALYs) were warded off during the program implementation period at the rate of 526 USD per DALY, exhibiting the intervention to be 'very cost-effective' by WHO definitions [10]. Therefore, this approach has also been endorsed by multilateral organizations namely WHO, the World Organization for Animal Health (WOAH), and the Food and Agriculture Organization of the United Nations (FAO), emphasizing the need for collaborative efforts to tackle zoonotic diseases [11]. In 2015, the world initiated action against rabies known as the 'Zero by 30' initiative, a global strategy to end dog mediated human rabies by 2030, with the collaboration of four organizations, including the WHO, FAO, WOAH, and the Global Alliance for Rabies Control (GARC). This global strategic plan highlights a country-centric, well-organized strategy to eliminate human death due to dog mediated rabies by 2023 [12]. The Association of South-East Asian Nations (ASEAN) also designated a cost-effective rabies control strategy, such as dog vaccination programme, supported by effective dog population management in the ASEAN Member States [4]. A robust health system plays a critical role in preventing and controlling infectious diseases by providing adequate support for early detection and prompt management of disease threats [13]. Health system preparedness for rabies control and prevention measures demands a critical evaluation of various aspects, including policies, practices, and infrastructure that are in place for the prevention and control of rabies within the healthcare and veterinary sectors. Health system preparedness is an essential component for the successful implementation of rabies control and prevention measures in both human health and animal health sectors. However, challenges persist across SEAR nations for consistent implementation of these components to control and prevent dog mediated rabies effectively. Therefore, the current scoping review intended to provide an in-depth overview of the health system preparedness of countries in the WHO South-East Asia Region (SEAR) for dog mediated rabies across the human and animal health sectors, focusing on the CDC (Centers for Disease Control and Prevention) framework of prevention, detection, and control [14].

Methods

The review methodology was developed based on the framework developed by Arksey and O'Malley and Levac et al., which includes the following stages [15].

1. Identifying the research question

For this review, the following research question was identified:
"What has been the overall health-system preparedness in rabies control and elimination in South-East Asia over the last decade?"

The JBI manual for Evidence Synthesis 2020 was used to develop the research question into PCC (Population, Concept, Context) format, where in this study context, the "Population" is the various stakeholders and components involved in rabies elimination efforts; this includes national government departments, healthcare professionals, veterinary agencies, local communities and animals at risk of rabies. The "Concept" is health system preparedness for rabies prevention, control and elimination and the "Context" is all countries under South-East Asia region as per WHO.

2. Identifying relevant studies

The published literature was systematically searched using journal databases, including PubMed, Embase, and Scopus. The search strategy was organized by main keywords in the research question and their synonyms, specifically "Health System", "Preparedness", Southeast Asia", "Rabies", and "Elimination". A combination of these keywords was utilized with the Boolean operators AND/OR. The search included grey literature on policy documents, animal bite management guidelines, and WHO publications available on the web. A manual search was conducted for the reference list of all articles included to confirm that all the relevant literature was included. Data was entered in Microsoft Excel 2019 for analysis.

3. Study selection

Inclusion criteria

The following was decided as the inclusion criteria:
1) studies focusing on health system preparedness for prevention, control, and elimination of dog-mediated rabies in SEAR countries, 2) written in English, and 3) primary research studies and grey literature resources from January 2013 to November 2023.

Exclusion criteria

Studies were excluded based on the following criteria:
1) Case reports that mainly focus on symptoms and treatment modalities for rabies, 2) studies focusing on the safety and efficacy of available Rabies vaccines, 3) systematic and scoping reviews, 4) perspective papers, book chapters, commentary and editorial papers, and conference papers.
All retrieved citations underwent three stages of the screening process: title, abstract, and full-text screening. Two researchers independently participated in reviewing all retrieved articles, and studies that complied with the predetermined inclusion and exclusion criteria were selected. The reviewers commenced with the blinded screening of the full texts once all the authors agreed on the selected studies.

4. Charting the data

Data were extracted from eligible articles as per the recommendations by Arksey and O'Malley [15]. The data were recorded by consolidating and understanding the data as per key themes. A data charting form was

developed to ensure relevant variables and themes were incorporated to answer the research question. Data were recorded from each article using MS Excel spreadsheets to ensure the comparability of extracted data among the articles.

5. Collating, summarising, and reporting the results

The findings of the review were summarized and reported according to the primary domains of the data extraction templates, and the findings were organized in such a way that addressed the review objectives. The results were reported based on the Preferred Reporting Item for Scoping Reviews (PRISMA-ScR) guidelines [16]. The result part is divided into three broad themes, including prevent, detect, and respond, as per the CDC framework [14]. In addition, each theme was elaborated under various categories such as Prevent: Pre-exposure prophylaxis and Post-exposure Prophylaxis vaccination, Rabies Awareness in the Community, Capacity Building, and Workforce Readiness, Inter-Sectoral Collaboration for Rabies Prevention and Control, Practise of One Health Approach; Detect: Reporting mechanisms for Rabies, Laboratory Diagnostic Capacity; Response: Dog Population Management and Mass Dog Vaccination, Dog Ownership.

Results

Characteristics of included studies

The PRISMA flow diagram summarizes the selection process (Fig. 1) for studies. Initially, 5,408 articles from different databases were identified. After removing 1,297 duplicates, 4,111 articles were included for the title and abstract screening. After these, 1,348 articles were excluded, as they were case reports, clinical trials, reviews or editorials, articles not published in the English

Fig. 1. PRISMA Diagram [16].

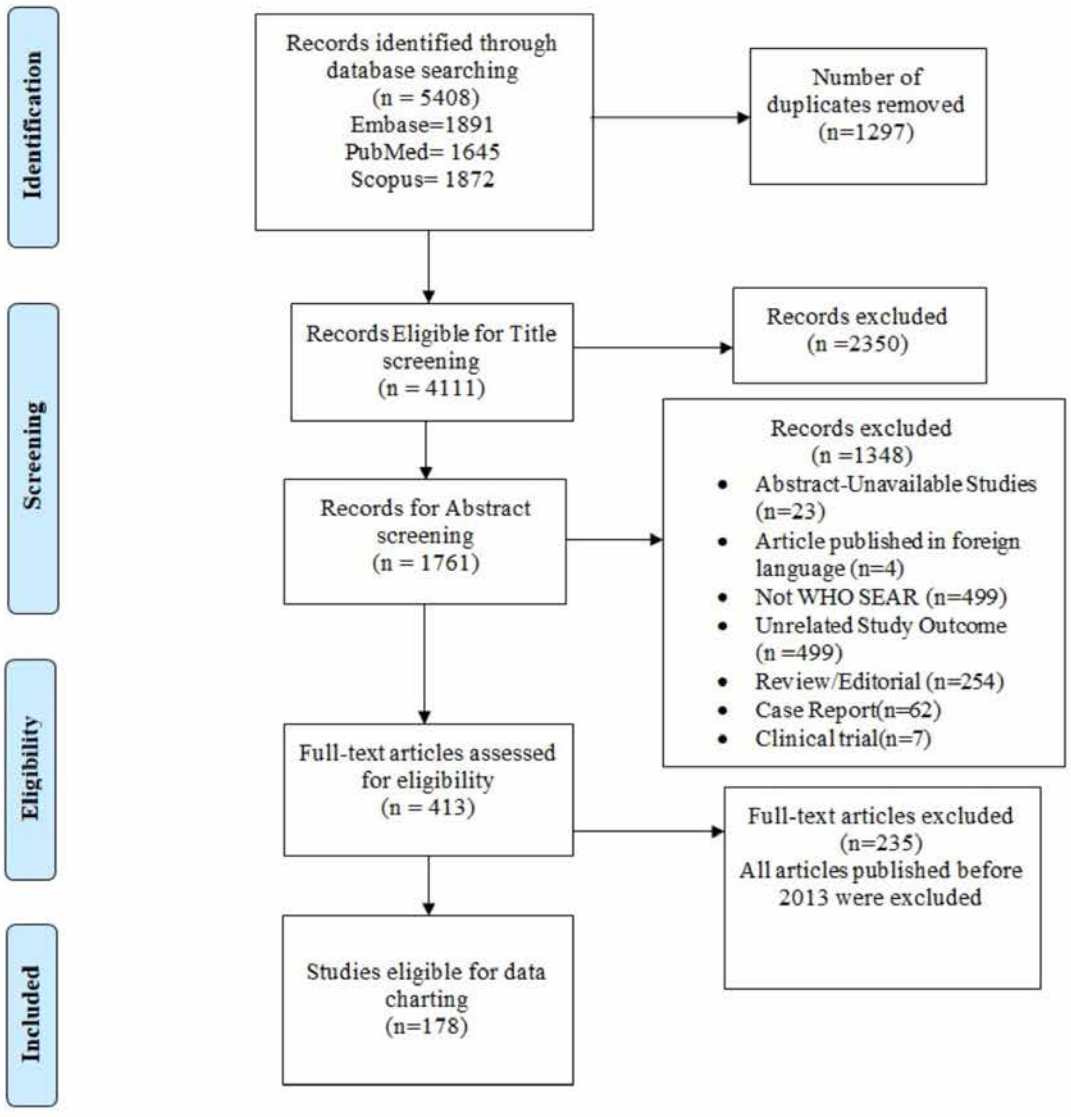
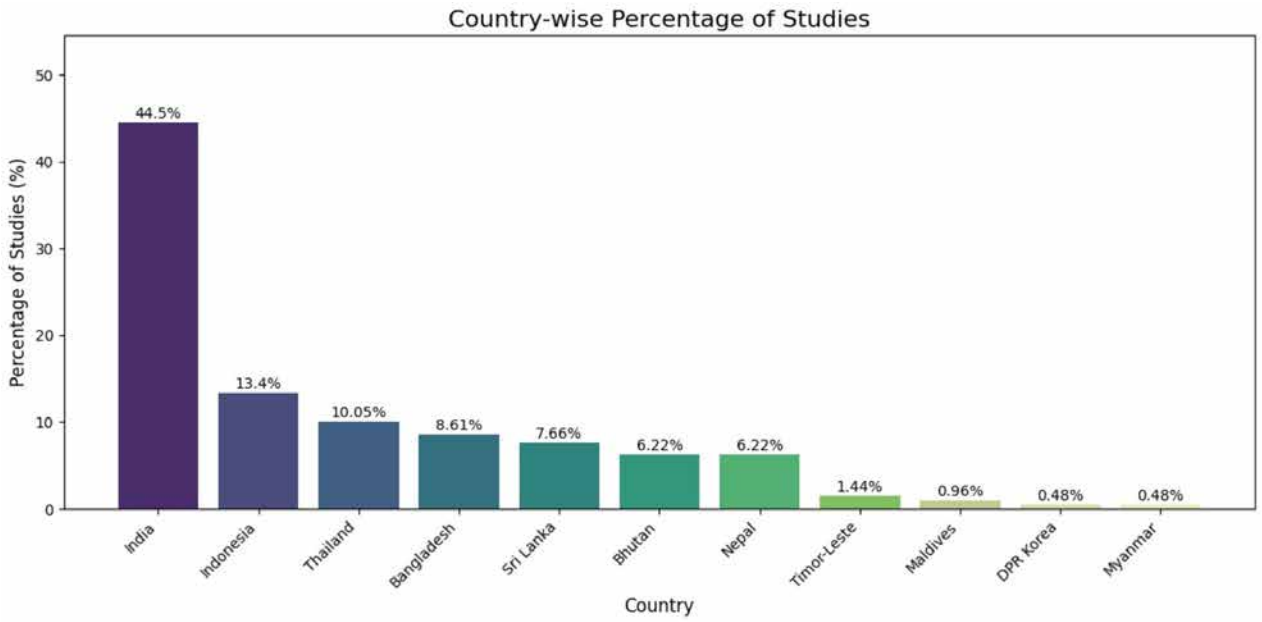


Fig. 2. Country-specific distribution of research based on published evidence in the South-East Asia Region.



language, studies not from SEAR countries, abstracts with unavailable studies, studies outcomes that did not match the objective of the review and articles published before 2013. The remaining 413 articles were included for review, with 178 studies meeting the eligibility criteria.

One of the significant findings from the review highlights the inadequate availability of data on the health system preparedness for dog mediated human rabies in rabies prevention, detection, and control efforts in SEAR countries like Myanmar and the Democratic People's Republic of Korea (DPRK Korea) During the review, we found that the highest number of publications related to rabies preparedness was from India, constituting 44.5% and the lowest number of publications was from Myanmar and the DPRK Korea, accounting for 0.48% of the total (Fig. 2). Relevant published articles were not identified from Timor Leste or the Maldives. Notably, the first human rabies cases were reported in the western part of the island of Timor Leste, which was rabies-free until May 2023 [17].

Publication-based trend analysis of rabies related studies conducted across SEAR countries from 2013 to 2023, highlights a regional disparity in rabies research (Figure 3). India consistently contributed to the highest number of studies with notable peaks in 2019 (24 studies), 2020 (11 studies) and 2022 (15 studies) demonstrating proactive research activity during these years. Other countries such as Bangladesh, Bhutan, Nepal, and Thailand, showed lower research activity, with minor fluctuations. Maldives, Myanmar, Sri Lanka, and Timor-Leste contributed minimally, generally ranging from 0 to 4 studies per year. Overall, the trend emphasizes the need for increased and systematic research in countries with low study output.

Prevent

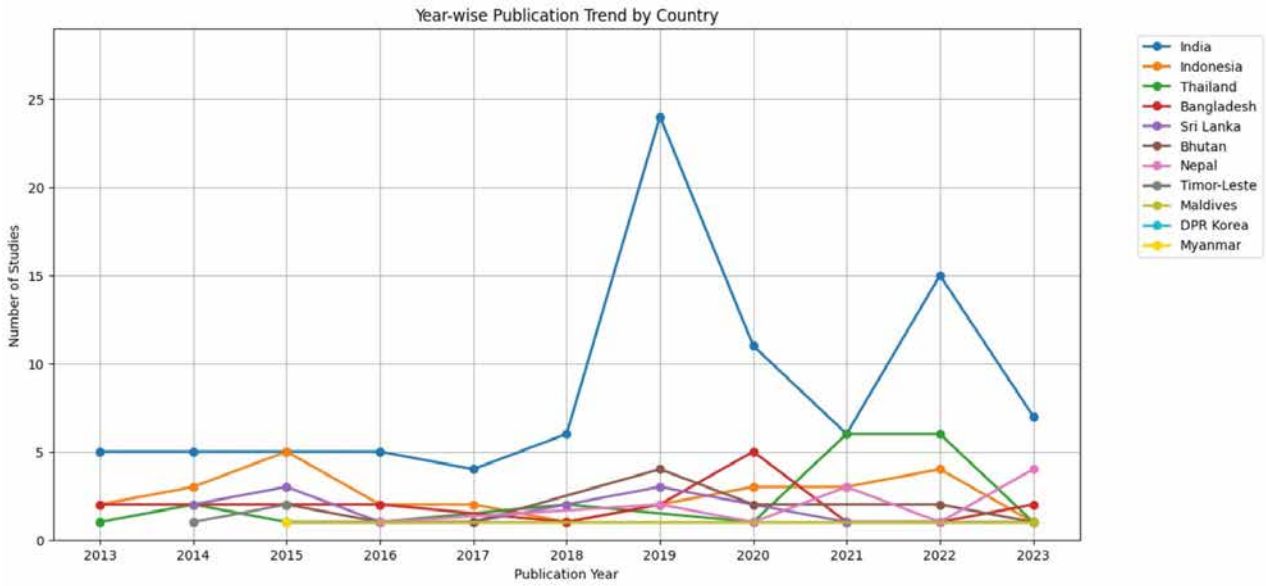
Pre-exposure prophylaxis (PrEP) and Post-exposure Prophylaxis (PEP) Vaccination

The findings identified that the implementation and adoption of PrEP and PEP vaccination programs have significant variations across South-East Asia. In Thailand, greater emphasis has been given to oral rabies vaccines (ORV) for dog and mass dog vaccination (MDV) over specific human vaccination programs [18]. The study's findings from Bangladesh, Bhutan, and Sri Lanka show that while rabies vaccines were available only at selected health facilities, often at a nominal or free of cost, availability of vaccine and distribution challenges often hinder accessibility, especially in rural areas [19]. A significant portion of Bangladesh's population (68.8%) relies on traditional healers to seek treatment after animal bites, including dog bites, causing low uptake of post-exposure prophylaxis [20, 21]. Evidence from India and Bhutan suggests that many people (56% and 78.2% of the participants) followed standard measures such as washing the bite wound with soap and water, followed by a dog bite [22-25]. In Nepal, basic wound care after a dog bite was most commonly practiced among upper-class people [26]. Obtaining pre- and post-exposure prophylaxis has been challenging for Indonesia due to inaccessible topographic areas, limited facilities, inadequate vaccine supply, lack of human resources, and the high cost of post-exposure treatment for humans [27-29].

Rabies awareness in the community

Studies from Thailand show that broadcasting plays a critical role in increasing awareness of rabies among the wider population, but there is a need to address

Fig. 3. Global Trends in Rabies Research Publications (2013-2023).



the importance of seeking medical intervention and adherence to the PEP regimen [30, 31]. In Bangladesh, studies indicate a lack of knowledge and belief in cultural myths and dogma among people, leading them to seek treatment from traditional healers [20, 21, 32, 33]. Over the years, people's level of awareness has changed. Still, there was a significant gap in knowledge about rabies prevention, treatment, and PEP regimens among populations, especially in rural populations of India [34-36]. In Bhutan, most of the participants (98%) had heard about rabies from different sources, but only a few followed post-exposure prophylaxis measures, revealing the need for mass education on rabies [25]. In Nepal, limited access to education, transportation, and medical facilities due to topographical challenges in hilly and Himalayan regions, impending rabies awareness campaigns, and control efforts [37-39]. The studies suggest community engagement, such as door-to-door mapping, GPS tracking, and the use of digital tools like SMS alerts, enhances public participation in rabies control efforts in Indonesia, but still, there are requirements for health education to increase public awareness about rabies, especially to the remote places where access to healthcare and vaccination services is limited [40-42]. In Sri Lanka, rabies prevention efforts have extensively prioritized community education with initiatives to incorporate rabies education into the school syllabus and empower the community through radio messages, educational videos, school campaigns, and print media, but studies suggest low participation of people in health education programs [9, 43].

Capacity Building and Workforce Readiness

The evidence suggests, in Thailand, over the years, there has been an emphasis on training the physicians, field staff, and volunteers to distribute of animal vaccine baits to the animal vaccination teams [44, 45, 18]. The findings from Bangladesh underscore the need for structured training modules for frontline health workers on rabies management [21]. Training programs were conducted in India for various community groups incorporating healthcare workers, village leaders, Primary Health Centre (PHC) staff, and auxiliary nurse midwives (ANMs); there was still a notable knowledge gap in various aspects of rabies control efforts, including understanding PEP regimens and management of animal bite injuries [46-48]. Bhutan's rabies control policy prioritized training on vaccine techniques and handling emergencies related to rabies exposure for the healthcare workers, which was reflected by the studies that indicate doctors and nurses are trained on PEP protocols and rabies vaccines are administered by trained staff for both the Expanded Program on Immunization (EPI) and rabies program [49, 19]. The rabies policy in Nepal stresses training for healthcare workers to equip them well to handle cases effectively; however, the evidence shows there are prerequisites for structured training for both healthcare workers and veterinarians in Nepal [50, 51]. The policy highlights training for animal health and health workers for mass dog vaccination campaigns, planning, analysing vaccination data, and PrEP/PEP administration in Indonesia and Sri Lanka [52, 53]. In Indonesia, training programs are conducted for various stakeholders from animal health sectors, including vaccinators, field teams to train in dog handling, laboratory staff, and veterinary staff received training in both dog vaccination and sampling [53, 54]. In Sri Lanka, doctors and nurses were trained in PEP protocols. Healthcare professionals also received training to utilize data platforms for monitoring and reporting rabies cases to assist in decision-making about PEP administration and tracking treatment outcomes [55, 19].

Inter-Sectoral Collaboration for Rabies Prevention and Control

The rabies control policies across SEAR countries emphasized collaboration and coordination among key stakeholders. In Thailand, local governments have collaborated with Non-Governmental Organizations (NGOs) and international partners, namely the United States Agency for International Development (USAID), to improve rabies control strategies [18]. Bangladesh also advocates for collaboration among various stakeholders, such as government agencies, NGOs, and community organizations [32, 56]. In India, mass vaccination campaigns, resource management, and community engagement were ensured through collaboration with Mission Rabies, local veterinary authorities, and other health departments [57, 58]. In Bhutan, there is a demand for improved coordination between human health and animal departments to enhance rabies control and prevention [59]. Similarly, the rabies control policies of Nepal, Indonesia, and Sri Lanka also emphasized the collaboration between the health sector, community organizations, livestock sector, and other relevant stakeholders to strengthen rabies control efforts [4, 51, 60]. Implementation of successful vaccine campaigns and capacity building was provided either through collaboration with local municipalities, NGOs, and community leaders or partnership with various international agencies such as World Animal Protection and other embedded agencies (*e.g.* FAO) in Nepal, Indonesia, and Sri Lanka [61-63].

Practice of the One Health approach

The One Health approach was observed to be an essential role in strengthening rabies surveillance by connecting animal bite surveillance with human rabies prevention and implementing mass dog vaccination to eliminate rabies [46, 37]. The rabies control policies of various countries reflect different levels of incorporation of the One Health approach. While most countries like Thailand, India, Bhutan, Sri Lanka, Myanmar, and the DPRK Korea have advocated a comprehensive one-health approach towards rabies prevention and control, others like Bangladesh, Nepal, and Indonesia have not explicitly mentioned it in their policies. While Thailand has limited evidence on the integration of the One Health approach in dog-mediated rabies control strategy, on the other side India has successfully demonstrated the feasibility and cost-effectiveness of a collaborative One Health approach for human rabies elimination at the state level by integrating public education, mass dog vaccination, and rabies surveillance [10]. The evidence from Bangladesh, Nepal, and Bhutan shows a need for a multi-dimensional approach that combining veterinary and medical capacity, which is more effective in rabies prevention for the respective countries [33, 64-67]. During emergency rabies response activities in Indonesia, the Rapid Response Team (RRT) involves animal and human health sectors, reflecting a One Health approach [28, 61]. The evidence from Sri Lanka highlighted that the execution of the rabies control program by incorporating the One Health approach will ensure efficient response and reporting of animal bite cases from the community through human and animal health officers by developing a digital tool that integrates public health data as well as animal health data [42].

DETECT

Reporting Mechanisms for Rabies

Effective reporting mechanisms are essential to control rabies across different SEAR countries. PEP human rabies cases in Thailand are reported to the National Database for treatment. Also, village health volunteers record dog vaccination coverage data and report it to community leaders, who, in turn, report it to the higher authority (the municipal, provincial, and national governments) [29, 30]. Studies from Bangladesh show limited evidence regarding reporting mechanisms in both the human health and animal health sectors for the detection of rabies. In India, there is the National Action Plan for Rabies Elimination (NAPRE). Complimenting this, periodic reporting is carried out at all levels through the Integrated Health Information Platform (IHIP), an online portal of the Integrated Disease Surveillance Program. Despite these efforts, disparities in reporting practices were seen in India, where rabid dog bite cases were reported even from higher socio-economic backgrounds [68]. While health facilities are provided with monitoring tools, PEP data are not consistently reported to the central level as there is a lack of a mandatory reporting system for rabies PEP in Bhutan [19]. Even in Nepal, underreporting of human rabies cases remains a significant challenge due to insufficient monitoring and coordinated approach despite having a national policy that mentions structured tools such as animal bite and rabies treatment forms to ensure timely reporting [45, 48, 69]. Reporting is mandatory for both human and animal rabies cases in Indonesia, reflected through the evidence, where once a case is reported to the public health authority, further coordinating with animal health officers for appropriate action [27, 42]. According to Sri Lanka's rabies control policies, every individual receiving PET (Post-Exposure Treatment) must be registered in the animal bite registry of the hospital, which is maintained by the rabies unit or OPD (Outpatient Department). Each rabies unit was required to send a summary of PET cases to the Public Health Veterinary Services (PHVS), denoted by the study, where trained nursing officers entered each bite incident at the hospital's rabies clinic. Also, reporting dog bite cases through apps has enhanced transparency for case reporting and vaccination monitoring [70, 61].

Surveillance System

Most SEAR nations have developed surveillance systems to control rabies that ensure early detection and prompt monitoring and detection of rabies cases across countries. In Thailand, the national rabies surveillance system, Thai Rabies Net (TRN) is utilized to evaluate the achievements of vaccination campaigns and monitor rabies outbreaks [18]. Setting up a

laboratory for rabies diagnosis and implementing an active surveillance system in Bangladesh to monitor emerging patterns and trends for both human and animal rabies cases [71]. The rabies control policy in India advocates a robust surveillance system for both human and animal rabies cases, yet animal bite cases are observed to be underreported, suggesting a need for strengthening surveillance systems to track rabies cases more effectively [58, 72, 73]. Bhutan's policy also mentioned a robust surveillance system for the human and animal sectors, but there is insufficient data on detailed surveillance systems [19]. The rabies control policy of Nepal has not explicitly mentioned the surveillance system, but the study indicates that the rabies surveillance systems in Nepal are improving [60]. In Indonesia, National surveillance for animals and humans produces data used as epidemiological indicators to report rabies cases to international databases like the WHO and WOAH. Integration of the existing surveillance system with a community-based surveillance approach is one of the approaches to strengthen the surveillance system in Indonesia [74, 75]. Sri Lanka mandates a strong surveillance system to monitor both human and animal rabies cases as per the rabies control policy, but there were insufficient data from the studies that shed light on its surveillance system pertaining to rabies control in both human and animal sectors [54].

Laboratory Diagnostic Capacity

In Thailand, laboratories are utilized for animal rabies and animal sample testing, commonly collected during surveillance [18]. India's rabies control policy highlights various algorithms for antemortem and post-mortem laboratory diagnosis for human rabies. For ante mortem cases, Reverse transcription polymerase chain reaction (RT-PCR), Rapid Fluorescent Foci Inhibition Test (RFFIT), and Fluorescent Antibody Virus Neutralization (FAVN) are employed. In the case of post-mortem, tests like Direct Fluorescent Antibody Test (DFAT) and Nucleic Acid Amplification Test (NAAT) are utilized [76, 77]. However, the existing evidence from India shows that biochemical profiles were used to assess treatment effectiveness for rabies Rapid Fluorescent Focus Inhibition Tests (RFFIT) are available at a WHO Collaborating Centre for Rabies Research [44, 78]. Advanced genome sequencing techniques confirm rabies infection for both human and animal cases [79]. Although laboratory capacity details were not explicitly mentioned, medical institutions were noted to have facilities for diagnosing both human and canine rabies [80, 81]. Despite all these, maintaining the cold chain has become a significant challenge during sample transportation [78]. ELISA is the most commonly used measure to identify rabies antibody levels in dog serum in Nepal [60]. Animal rabies cases are confirmed using the Fluorescent Antibody Test (FAT) at the Central Veterinary Laboratory (CVL), and human rabies cases are identified using indirect immune-enzymatic assays [82, 83]. Laboratory infrastructure is limited in Indonesia, which poses a challenge for rabies detection in both humans and animals [51]. However, the animal health sector conducts rabies testing for rabies-suspected dogs, and Direct Fluorescent Antibody Testing is used to test the brain samples of suspected rabid dogs at the Disease Investigation Center [84]. Other SEAR countries like Bangladesh, Bhutan, and Sri Lanka have inadequate existing evidence on the diagnostic capacity of rabies detection in both human and animal rabies cases.

Response

Dog Population Management and Mass Dog Vaccination

Dog population management and mass dog immunization are critical aspects of rabies control policies for most South-East Asian countries. Thailand focuses on vaccinating free-roaming dogs (FRD) that are hard to reach, stressing responsible dog ownership to reduce the number of stray dogs [85, 44]. The traditional approach of culling dogs in Bangladesh has been less practical for dog population management and has led to the transition to mass vaccination with ORV and CNVR [58, 34]. Even in India, FRD is a significant concern, and to tackle this challenge, various measures like animal birth control (ABC), garbage management, and seasonal planning for neutering campaigns to manage dog populations are indicated [86, 57, 49]. Rabies control is more structured in Bhutan by managing FRD by capturing, neutering, and vaccinating them through mass dog vaccination and the program [60]. Studies from Nepal emphasize the need for stray dog population management due to high reproductive rates [50]. In Indonesia, dog population management for rabies primarily revolves around the non-systematic culling of FRD [87, 88, 89]. Mass dog vaccination campaigns are operated through an app in Sri Lanka, and even dog population control strategies are focused on combination of dog vaccination and birth control measures [90].

Dog Ownership

Responsible dog ownership is an essential component in rabies control and prevention. Countries like India, Sri Lanka, Indonesia and the DPRK Korea have promoted responsible dog ownership in their policies for effective vaccination campaigns and management strategies. In India, evidence implies the need to emphasize responsible dog ownership in sterilization, registration, and vaccination of dogs, which is critical in managing the dog population and reducing FRD [86]. In Indonesia, the free roaming of owned dogs' complicate vaccine coverage, indicate the need to educate owners about routine vaccination and sterilization [88, 89]. In Sri Lanka, responsible dog ownership is emphasized by tailored rabies vaccine strategies [61, 63]. Prioritization of dog ownership is not well evident in Thailand, Nepal, Bhutan, and Bangladesh, emphasizes the need to promote responsible dog ownership among the population.

Discussion

The present review provides a comprehensive overview of health system preparedness for dog-mediated rabies across the WHO South-East Asia Region (SEAR). While several countries in the region have made notable progress, rabies continues to be endemic in most SEAR countries including Bangladesh, Bhutan, DPRK Korea, India, Indonesia, Myanmar, Nepal, Sri Lanka, and Thailand [91]. Although Myanmar and DPRK Korea possess national rabies policies, this review highlights a striking paucity of published evidence on operational health-system preparedness in these settings [92], suggesting institutional and surveillance gaps rather than true absence of disease burden.

While the original findings demonstrate considerable heterogeneity in rabies control strategies within SEAR, a broader synthesis reveals that progress is driven less by technical capacity alone and more by political will, governance strength, and sustainable financing. Global comparative analyses consistently show that countries with stronger governance structures, stable public financing, and legal frameworks for multisectoral coordination achieve higher levels of epidemic preparedness, independent of income status [93].

Within SEAR, Thailand exemplifies this pattern by sustaining strong political commitment, advanced surveillance infrastructure (Thai Rabies Net), and consistent mass dog vaccination (MDV) efforts [18, 31, 44]. Sri Lanka similarly demonstrates institutionalized reporting systems, workforce training, and integrated dog vaccination and birth-control strategies [9, 43, 90, 19]. In contrast, countries such as Nepal and Bangladesh continue to face fragmented governance, inconsistent funding, and weak intersectoral enforcement despite possessing technical guidelines and international support [20, 39, 60].

Beyond governance, the review highlights the influence of socioeconomic determinants and structural determinants. Rural residence, geographic isolation, poverty, limited health literacy, and reliance on traditional healers particularly evident in Bangladesh and parts of India continue to delay timely uptake of PEP [20, 22, 34, 35]. These findings highlight that structural inequities and weak primary healthcare systems significantly undermine rabies elimination despite the availability of effective vaccines. In various endemic regions, most notably in mountainous areas like Nepal and parts of India, topographical obstacles intensify rabies mortality. These geographical challenges create significant gaps in healthcare access, strain already limited personnel resources, and lead to frequent disruptions in the medical supply chain [39, 40].

Benchmarking SEAR against other regions further contextualizes performance. Latin American countries such as Mexico and Brazil achieved near-elimination of canine rabies through decades of strong municipal governance, compulsory MDV, surveillance and sustained domestic financing [94]. Conversely, many African and Asian countries continue to struggle with widespread stray dogs, fragmented veterinary public health systems, weak financing, and inconsistent vaccination coverage have allowed sustained transmission of the virus between animals and humans. Limited health-care resources and the high cost or poor availability of PEP further increase population vulnerability [95].

The collective evidence indicates that rabies elimination is fundamentally a governance and development challenge, not merely a biomedical one. Countries that embed rabies elimination within long-term national health financing frameworks, institutionalize One Health governance, and ensure predictable domestic funding demonstrate faster and more sustainable progress. This is evidenced by the stark contrast between the domestic-led success in Latin America and the fragmented, donor-dependent programs often seen in high-burden regions [94].

Within SEAR, strengths such as India's expanding One Health initiatives [10], Bhutan's structured training and community engagement [28, 19], and Sri Lanka's integrated reporting and surveillance [9, 43, 90] provide important foundations. However, persistent challenges uneven vaccine access, under-reporting of animal bites [22, 68], diagnostic capacity limitations [78], and workforce shortages [46-48] continue to impede uniform regional advancement.

Ultimately, the attainment of the 'Zero by 30' objective in SEAR countries is contingent upon a transition from localized interventions to systemic integration. This process demands the stabilization of national health budgets, improved horizontal coordination across sectors, and the rectification of geographical inequities in PEP and MDV distribution. Crucially, these efforts must be supported by the development of resilient surveillance frameworks and high-fidelity laboratory infrastructure to ensure data-driven policy implementation

Strengths and Limitations

This review provides a detailed representation of SEAR countries, where the sectors with deliberate progress in rabies control measures and the areas that need to be considered. The review's strengths include grey literature on policy documents and animal bite management guidelines of SEAR countries, which provides a comprehensive understanding of health system preparedness for dog-mediated rabies in the region. However, in the review, we identified studies from SEAR, which do not represent data for health system preparedness of dog-mediated rabies across the human and animal health sectors.

Conclusion

Each SEAR country demonstrates distinctive strengths and challenges in the elimination of rabies. This review underlines that while, over the years, all countries

under the South-East Asian Region (SEAR) have made progress in rabies prevention and control efforts, although certain aspects need to be focused on and strengthened. Strengthening inter-sectorial coordination by linking both animal and human data for rabies surveillance, expanding public education, improvising health infrastructure, and strengthening vaccine accessibility could contribute to the control efforts in South-East Asia countries and enhance the global goal "Zero by 30" of ending dog-mediated human rabies deaths by 2030.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Data Availability Statement

The data set used for the current study is available as supplementary material in the manuscript (Tab. S1).

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Conflict of Interest Statement

The authors declare that they have no conflicts of interest.

Authors' Contributions

IG: formulating search strategy, search and screening articles, data extraction and analysis SUK: formulating search strategy, screening articles, data extraction, data analysis, and manuscript writing; MT: search and screening articles; NV: data analysis, third reviewer of conflict articles, guidance on methodology writing, and writing the manuscript; NS: searching and screening articles, data analysis, and writing the manuscript; AV: inputs on data analysis, writing, and reviewing of the manuscript; SN: inputs on data analysis, writing, and reviewing the manuscript; BK: inputs on data analysis, writing, and reviewing the manuscript.

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Tab. S1. Characteristics of Included Studies.

S.No	Author(s) (Year)	Country/Region	Study Design	Population	Sample Size	Key Findings	References
1	Mubashar et al. (2023)	Bhutan, India, Maldives, Nepal, Sri Lanka	Epidemiological Study	Dog bite victims	Not Specified	Regional rabies control requires mass dog vaccination, surveillance, and One Health collaboration.	[68]
2	Leelahapongsathon et al. (2023)	Thailand	Field Study	Free-roaming dogs	Not Specified	ORV integration improved vaccination of free-roaming dogs under a One Health framework.	[18]
3	Dhakal et al. (2023)	Nepal	Cross Sectional Study	Household heads	308	Integrated education, trained responders, strong healthcare systems, stakeholder collaboration, and mass dog vaccination are essential.	[96]
4	Fielding et al. (2023)	India	Mixed-Methods Study	Free-ranging dogs (FRD)	Not Specified	Standardized dog surveys improved assessment of sterilization coverage.	[97]
5	Lu et al. (2023)	Bangladesh	Retrospective Ecological Study	Cattle, buffalo, sheep, and goats	Not Specified	Higher education levels were associated with fewer livestock rabies cases.	[70]
6	Verma & Agarwal (2023)	India	Experimental Study Design	Preclinical medical students	Not Specified	Social media showed limited short-term impact on rabies awareness.	[98]
7	Shrestha et al. (2023)	Nepal	Retrospective Ecological Spatial Analysis	Data from VES and CVL	Not Specified	Spatial and seasonal rabies patterns support pulse vaccination in high-risk districts.	[81]
8	Karamoy et al. (2023)	Indonesia	Qualitative Study	Stakeholders from five sectors	Not Specified	Fragmented coordination and weak data systems hinder rabies prevention.	[87]
9	Giri (2023)	India	Cross Sectional Study	Animal bite cases	Not Specified	Strengthened community education is required despite high general awareness.	[99]
10	Balaraju et al. (2023)	India	Cross Sectional Study	MBBS Interns	Not Specified	Interns knew PrEP guidelines but lacked detailed PEP knowledge.	[100]
11	Cuddington & McAuliffe (2023)	India	Economic Modelling Study	Free-roaming dogs	Not Specified	Achieving >70% dog vaccination is essential for eliminating human rabies.	[101]
12	Tamanna et al. (2023)	Bangladesh	Cross Sectional Study	Patients given first dose of rabies IG	Not Specified	Delays in completing PEP were linked to poor knowledge and access barriers.	[102]
13	Rajpoot et al. (2023)	India	Cross Sectional Study	Visitors at Anti-Rabies Clinic	Not Specified	Incomplete disease knowledge persisted despite general awareness of rabies preventability.	[103]
14	Dhakal et al. (2023)	Nepal	Cross Sectional Study	Households	308	Survey findings guided targeted rabies prevention policies.	[37]
15	Laorujisawat et al. (2022)	Thailand	Cross Sectional Study	Primary school students	Not Specified	School-based rabies education improved preventive knowledge.	[104]
16	Subrata et al. (2022)	Indonesia	Mixed-Methods Study	Veterinarians, officers, leaders, dog owners, workers	Not Specified	Digital tools integrated with vaccination/ sterilization strengthened One Health rabies surveillance.	[40]
17	Saepudin et al. (2022)	Indonesia	Case-Control Study	Dog bite victims	Not Specified	Prevention depends on domestic animal vaccination, education, and surveillance.	[38]
18	More & Jadhav (2022)	India	Pre-experimental (pre-post test)	Caregivers in a hospital	100	Structured teaching significantly improved caregivers' knowledge of anti-rabies vaccination.	[105]

Tab. S1 *(follows).*

S.No	Author(s) (Year)	Country/Region	Study Design	Population	Sample Size	Key Findings	References
19	Rode (2022)	India	Pre-experimental (pre-post test)	Adults in Pune city	60	Health education improved community awareness of PEP following dog bites.	[106]
20	Kiratitana-olan et al. (2022)	Thailand	Qualitative Study	Permanent residents (urban, suburban, rural)	Not Specified	Multisectoral collaboration and community engagement sustained rabies-free status.	[29]
21	Chaudhari et al. (2022)	India	Descriptive and Evaluative study	Street dogs	Not Specified	Digital tools and CNVR improved dog population management and rabies vaccination outcomes.	[107]
22	Vanak et al. (2022)	India	Descriptive Observational Design	Dogs	Not Specified	Passive surveillance supports rabies monitoring, but revaccination gaps hinder elimination goals.	[108]
23	Manna et al. (2022)	India	Cross Sectional Study	Animal Bite Victims	Not Specified	PEP adherence linked to socio-economic status and awareness levels.	[24]
24	Aptriana et al. (2022)	Indonesia	Qualitative study	Relevant stakeholders	Not Specified	One Health coordination improved surveillance and vaccination despite resource constraints.	[27]
25	Bariya et al. (2022)	India	Interventional Study	Staff Nurse	Not Specified	CME programs improved nurses' awareness of rabies transmission, though protocol gaps remained.	[109]
26	Lhendup & Wangdi (2022)	Bhutan	Cross Sectional Study	Volunteer household members	55 households	Cultural beliefs and awareness gaps persist despite good rabies knowledge.	[25]
27	Jethani et al. (2022)	India	Retrospective cross-sectional study	Animal bite cases	Not Specified	Vaccine shortages forced patients to travel, underscoring prevention and supply-chain gaps.	[110]
28	Dua et al. (2022)	India	Retrospective record-based study	Animal bite cases	Not Specified	High animal-bite burden highlights need for expanded education and prophylaxis services.	[111]
29	Gibson et al. (2022)	India	Intervention study	Human and canine populations	Not Specified	Integrated surveillance, vaccination, and education supported rabies elimination in Goa.	[112]
30	Gongal et al. (2022)	India, Nepal, Sri Lanka, Thailand	Mixed-methods observational study	Health facilities and PEP providers	Not Specified	COVID-19 disrupted services, but PEP availability was largely maintained.	[113]
31	Lungten et al. (2022)	Bhutan	Interventional study	School Students	Not Specified	Short educational sessions significantly improved student rabies knowledge.	[114]
32	Evans et al. (2022)	India	Prospective observational study	Free-ranging dogs (FRD)	Not Specified	Annual campaigns achieved 70% coverage but required sustained implementation.	[115]
33	Nadal et al. (2022)	India	Mixed-method Study	Healer, Temple Caretaker	Not Specified	Engagement with faith healers is essential to address cultural barriers to rabies prevention.	[116]
34	Gill et al. (2022)	India	Dog Survey	Dog population	Not Specified	Inconsistent stray dog counts limit effective planning of control programs.	[117]
35	Sararat et al. (2022)	Thailand	Individual-based modeling study	Canine rabies cases	Not Specified	Modeling showed that increased vaccination and reduced dog populations are critical for rabies control.	[118]
36	Bharani (2022)	India	Cross Sectional Study	Individuals from rural community	Not Specified	Very low awareness of wound washing and vaccine availability in rural communities.	[119]
37	Kanankege et al. (2022)	Thailand	Retrospective study	Government and open-source data	Not Specified	Integrated One Health surveillance supported rabies control though reporting gaps persisted.	[30]

Tab. S1 *(follows).*

S.No	Author(s) (Year)	Country/Region	Study Design	Population	Sample Size	Key Findings	References
38	Royal et al. (2022)	India	Cost effectiveness analysis	Children	Not Specified	PrEP was highly cost-effective for high-risk children in rabies-endemic settings.	[120]
39	Khamduang et al. (2022)	Thailand	Cross Sectional Study	Village health volunteers	Not Specified	Trained village volunteers effectively supported animal rabies vaccination.	[121]
40	Silva et al. (2022)	Indonesia	Observational ecological study	Free-roaming dogs in rural/urban areas	Not Specified	Habitat-based tracking supported targeted dog vaccination strategies.	[122]
41	(Ross et al., 2022)	Bangladesh	Cross Sectional Study	Urban and peri-urban residents	Bangladesh	Improved PEP access and public awareness are key to rabies elimination by 2030	[123]
42	Tipsarp Kittisiam et al. (2021)	Thailand	Cross Sectional Study	Dogs	Not Specified	Network modeling identified high-risk dogs to guide targeted vaccination.	[124]
43	Rana et al. (2021)	Bangladesh	Cross Sectional Study	Community people, healthcare professionals, vets	Not Specified	Knowledge gaps and preference for dog culling hinder elimination efforts.	[21]
44	Mani et al. (2021)	India	Case Study	Asiatic wild dogs (*Cuon alpinus*)	Not Specified	Laboratory-confirmed rabies highlights need for mass vaccination of domestic dogs.	[78]
45	Pal et al. (2021)	Nepal	Retrospective Epidemiological Study	Various animal species	Not Specified	Long-term surveillance, mass vaccination, and One Health coordination are key to rabies control.	[63]
46	Fielding et al. (2021)	India	Model Analysis	Adult female free-roaming dogs	7,743	Understanding dog reproductive seasonality improves effectiveness of neutering and population management.	[125]
47	Saleem et al. (2021)	India	Record-based cross-sectional study	Dog bite victims	Not Specified	Strengthened surveillance, responsible ownership, and dog population control are essential.	[126]
48	Pal et al. (2021)	Nepal	Retrospective Study	Dog bite victims	Not Specified	Improved PEP use, surveillance, and One Health collaboration reduce rabies risk.	[36]
49	Taneja et al. (2021)	India	Retrospective Cross-Sectional study	Dog bite victims	Not Specified	Community awareness, vaccination, and data-driven dog population control enhance rabies prevention.	[127]
50	Rehman et al. (2021)	Indonesia	Cross sectional study	Respondents of different demographics	432	Major gaps in post-bite care-seeking behavior indicate urgent need for community education.	[39]
51	Premashthira et al. (2021)	Thailand	Cross Sectional Study	Dog owners	Not Specified	Public education should be prioritized over perception-based policy changes.	[128]
52	Sivagurunathan et al. (2021)	India	Cross Sectional Study	Residents	Not Specified	Primary care physicians play a key role in correcting community rabies misconceptions.	[129]
53	Weerapong Thanapongtharm et al. (2021)	Thailand	Retrospective analysis with spatial modeling	Animal rabies cases (dogs)	Not Specified	Implemented a national rabies control strategy involving mass dog vaccination, promotion of responsible dog ownership, strengthened surveillance and multisectoral collaboration under a One Health approach, contributing to improved rabies control.	[130]

Tab. S1 *(follows).*

S.No	Author(s) (Year)	Country/Region	Study Design	Population	Sample Size	Key Findings	References
54	Thanapongtharm et al. (2021)	Thailand	Dog surveys and spatial modelling	Owned and ownerless dogs	Not Specified	Surveillance systems and spatial planning supported effective dog vaccination strategies.	[131]
55	Chanachai et al. (2021)	Thailand	Field-based interventional study	Free-roaming dogs	Not Specified	ORV effectively reduced rabies risk among free-roaming dogs.	[43]
56	Warembourg et al. (2021)	Indonesia	Cross Sectional Study	Owned dogs	714	Targeting highly connected dogs improved vaccination efficiency.	[86]
57	Nale et al. (2021)	India	Observational Study	Vaccinated and owned dogs	Not Specified	Mass dog vaccination increased herd immunity through multisectoral collaboration.	[132]
58	Ubeyratne et al. (2021)	Sri Lanka	Cross Sectional Study	Residents in rural areas	Not Specified	Moderate PEP uptake but low education and vaccination hindered control efforts.	[133]
59	Christopher et al. (2021)	Indonesia	Cross Sectional Study	Community members in Songan Village	Not Specified	Community education and dog vaccination improved local rabies prevention.	[134]
60	Laorujisawat et al. (2021)	Thailand	Cross Sectional Study	Fourth-grade students	Not Specified	Protection-motivation based education improved rabies preventive behavior among school children.	[135]
61	Pal et al. (2021)	Nepal	Cross Sectional Study	Respondents from Nepal	5000	Preference for traditional healers and low vaccination knowledge increased rabies risk.	[64]
62	Rinchen et al. (2020)	Bhutan	Qualitative Risk Assessment	Dogs	Not Specified	Stronger coordinated public and expert engagement is required for rabies control.	[136]
63	Penjor et al. (2020)	Bhutan	Cross Sectional Study	Clinicians and human cases	Not Specified	Inconsistent PEP practices highlighted need for clinician training and coordination.	[48]
64	Rahaman et al. (2020)	Bangladesh	Cross Sectional Study	Local residents	Not Specified	Socio-economic barriers and myths reduced use of free rabies treatment services.	[137]
65	Zuhriyah et al. (2020)	Indonesia	Case Study	Outbreak affected population	>240,000	One Health–based PEP, mass dog vaccination, and workforce training are critical despite weak laboratory capacity.	[52]
66	Anandhan et al. (2020)	India	Cross-Sectional Study	Residents of Tamil Nadu	205	Public awareness, timely PEP, and dog vaccination are central to rabies prevention.	[138]
67	Gupta et al. (2020)	India	Cross-Sectional Study	University students	Not Specified	Student education improves awareness and supports community-level rabies prevention.	[139]
68	Marpaung & Monique (2020)	Indonesia	Qualitative study	Children in an endemic area	Not Specified	Rabies prevention in children relies on PEP access and targeted awareness programs.	[140]
69	Wallace et al. (2020)	Indonesia, India	Qualitative study	Dog populations globally	Not Specified	Parenteral vaccination remains primary; ORV, surveillance, and multisectoral collaboration strengthen One Health control.	[141]
70	Wani et al. (2020)	India	Cross Sectional Study	Patients with history of animal bite	Not Specified	Delayed PEP was associated with rural residence, low income, and referral barriers.	[142]
71	Alam et al. (2020)	Bangladesh	Cross Sectional Study	Dog-bite Victims	Not Specified	Low awareness and poor wound care increased exposure to rabies.	[143]
72	Rana et al. (2020)	Bangladesh	Retrospective cross-sectional study	Caregiver/relatives of deceased	Not Specified	Limited access to free vaccines and reliance on traditional healers led to fatal treatment delays.	[20]

Tab. S1 *(follows).*

S.No	Author(s) (Year)	Country/Region	Study Design	Population	Sample Size	Key Findings	References
73	Bashir et al. (2020)	India	Retrospective study	Dog bite victims	6172	Free ARV, surveillance and multisectoral coordination improved rabies control in high-risk areas.	[57]
74	Ghosh et al. (2020)	Bangladesh	Retrospective Study	Dog bite victims	Not Specified	Socio-cultural barriers and traditional healing limited PEP uptake, necessitating awareness and mass dog vaccination.	[66]
75	Gautam et al. (2020)	India	Cross Sectional Study	Institutional residents and stakeholders	Not Specified	Low vaccination coverage and weak community participation limited campus rabies control.	[144]
76	Gigante et al. (2020)	India	Cross Sectional Study	Rabies virus samples	Not Specified	Portable sequencing improved rabies surveillance capacity.	[145]
77	Belsare & Vanak (2020)	India	Agent-based modelling (ABM) simulation study	Free-roaming dog population	Not Specified	Underfunded CNVR programs limit rabies control without sustained One Health action.	[146]
78	Bonwitt et al. (2020)	Bangladesh	Observational field study	Free-roaming dogs	356	ORV combined with community engagement improved vaccination of free-roaming dogs.	[56]
79	Saleem et al. (2020)	India	Qualitative analysis	People living in Srinagar city	Not Specified	Low public preparedness increased vulnerability to dog bites.	[147]
80	Sabeena et al. (2020)	India	Intervention Study	Health Care Professionals	Not Specified	Mobile app improved guidance on rabies prevention and post-bite management.	[148]
81	Yurachai et al. (2020)	Thailand	Epidemiological study	Residents exposed to suspected rabid animals	Not Specified	Hospital-based electronic surveillance strengthened rabies monitoring and response.	[149]
82	Rimal et al. (2020)	Nepal	Cross Sectional Study	Vaccinated pet dogs	Not Specified	Training veterinary staff improved serological monitoring and vaccination effectiveness.	[82]
83	Larkins et al. (2020)	India	Cost-Effectiveness Case Study	Roaming dog and human population	Not Specified	Long-term sterilization and vaccination were cost-effective rabies control strategies.	[150]
84	Gibson et al. (2019)	India	Field-based comparative experimental study	Free-roaming dogs	Not Specified	Oral rabies vaccination effective for free-roaming dogs.	[151]
85	Gibson et al. (2019)	India	Field Survey	Dog population, vaccination staff	Not Specified	OBH vaccination reached more ownerless dogs than conventional methods.	[67]
86	Tiwari et al. (2019)	India	Cross-Sectional Study	Urban residents	204	Awareness gaps among low-SES groups; need targeted education and dog management.	[152]
87	Tiwari et al. (2019)	India	Observational Field Study	Free-roaming dogs	Not Specified	Tailored vaccination strategies and accurate dog population estimation are essential to achieve ≥70% coverage.	[153]
88	Tiwari et al. (2019)	India	Comparative observational study	Free Roaming Dog	Not Specified	Poor waste management undermined stray dog vaccination and birth-control programs.	[154]
89	Tiwari et al. (2019)	India	Cross Sectional Study	Free-ranging dogs (FRD)	Not Specified	Rapid online tools reliably estimated vaccination targets for FRDs.	[155]
90	Sreenivasan et al. (2019)	Bangladesh, Bhutan, India, Nepal, Sri Lanka	Cross-Sectional Study	Key informants from 23 countries	Not Specified	Large inter-country variation in PEP delivery; dog vaccination remains essential.	[156]

Tab. S1 *(follows).*

S.No	Author(s) (Year)	Country/Region	Study Design	Population	Sample Size	Key Findings	References
91	Li et al. (2019)	Bangladesh, Bhutan, Sri Lanka	Qualitative Study	Key informants from the public sector	Not Specified	One Health collaboration supported PEP delivery and animal vaccination.	[19]
92	Ojha (2019)	Nepal	Cross-Sectional Study	Street dogs	50	High antibody response in vaccinated dogs; highlighted need for surveillance and political commitment.	[60]
93	Brookes et al. (2019)	India	Observational Study	Farmers and householders	Not Specified	Informal information networks limit vaccination uptake, stressing need for formal surveillance systems.	[157]
94	Ashwath Narayana & Sudarshan (2019)	India	Record-based study	Human rabies cases and animal bite incidents	Not Specified	Improved PEP reduced cases but reporting and documentation gaps persisted.	[72]
95	Meunier et al. (2019)	India	Comparative observational field study	Free-roaming dogs	Not Specified	Systematic dog surveys are essential for planning vaccination campaigns.	[158]
96	Meunier et al. (2019)	India	Observational field study	Free-roaming dogs	Not Specified	>70% vaccination of free-roaming dogs achieved through coordinated One Health campaign.	[159]
97	Manoharan et al. (2019)	India	Quasi Experimental Study	Medical Students	Not Specified	Medical students lacked comprehensive training in rabies PEP protocols.	[160]
98	Narayana et al. (2019)	India	Mixed-Method Study	Stakeholders from govt. and private sectors	Not Specified	Gaps in PEP availability and coordination weakened rabies prevention efforts.	[161]
99	Sanjay et al. (2019)	India	Cross Sectional Study	General population	Not Specified	Low PrEP awareness necessitates public education campaigns.	[162]
100	Rinchen et al. (2019)	Bhutan	Cross Sectional Study	Cattle owners	562	High awareness but poor knowledge among cattle owners indicates need for stronger education.	[65]
101	Tiwari et al. (2019)	India	Cross Sectional Study	Rural residents of Maharashtra	127	Rural communities showed awareness but delays in treatment and poor ownership practices persisted.	[22]
102	Mani et al. (2019)	India	Descriptive Study	Officials from various sectors	Not Specified	Integrated medical-veterinary efforts maintained rabies-free status, requiring continued surveillance.	[71]
103	Penjor et al. (2019)	Bhutan	Cross Sectional Study	Dog-bite victims	Not Specified	Awareness and accessibility improved PEP adherence, though misconceptions caused delays.	[163]
104	Bharti et al. (2019)	India	Retrospective Study	Patients exposed to suspected rabid animals	Not Specified	Intradermal PEP with eRIG was effective and cost-saving.	[164]
105	Bharti (2019)	India	Retrospective Study	Animal bite patients	Not Specified	Wound infiltration with eRIG was effective and reduced costs.	[165]
106	Sánchez-Soriano et al. (2019)	Sri Lanka	Retrospective Study	Dogs Population	Not Specified	Coordinated vaccination campaigns achieved high dog coverage.	[166]
107	Srinivasan et al. (2019)	India	Mixed-method Study	General population	Not Specified	General awareness was high, but first-aid practices remained inadequate.	[167]

Tab. S1 *(follows).*

S.No	Author(s) (Year)	Country/Region	Study Design	Population	Sample Size	Key Findings	References
108	Ni et al. (2019)	Indonesia	Mixed method study	Dog and dog owners	Not Specified	Community-led veterinary and education programs reduced rabies risk but faced sustainability challenges.	[83]
109	Gill et al. (2019)	India	Prospective observational study	Canine and livestock populations	Not Specified	Community reporting improved rabies surveillance and dog management.	[168]
110	Amanatin et al. (2019)	Indonesia	Risk Assessment Study	Hunting dog	Not Specified	Vaccine shortages, cold-chain gaps, and limited workforce reduced dog vaccination coverage.	[26]
111	Hanumanthaiah et al. (2019)	India	Cross Sectional Study	Individuals attending anti-rabies clinics	Not Specified	ARCs require better training, supplies, and standardized reporting.	[169]
112	Kapoor et al. (2019)	India	Observational Cross-sectional study	Attendees of the anti rabies clinic	Not Specified	Knowledge of wound washing existed, but overall rabies prevention awareness was inadequate.	[170]
113	(Haradanhalli & D Hanumanthaiah, 2019)	India	Cross-sectional, multicentric survey study	Health system facilities and officials responsible for rabies biologicals logistics	India	The National Rabies Control Programme emphasizes training and monitoring, while gaps remain in vaccine distribution and cold chain management.	[171]
114	Hampson et al. (2019)	India	Modeling Study	Individuals exposed to potentially rabid animals	Not Specified	PEP is cost-effective, but mass dog vaccination remains essential for elimination.	[172]
115	Kanwal & Devgun (2018)	India	Cross-Sectional Study	Respondents	400	Significant gaps in ARV access and qualified care among dog bite victims.	[173]
116	Karmakar et al. (2018)	India	Cross Sectional Study	Dog bite victims	Not Specified	Proper wound care was common, but public awareness and street dog control need strengthening.	[174]
117	Behera (2018)	India	Cross Sectional Study	Veterinary staff	Not Specified	Veterinary staff showed poor rabies risk perception and low PrEP coverage, indicating training gaps.	[175]
118	Kasemsuwan et al. (2018)	Thailand	Field Study	Street dogs	Not Specified	ORV during mass campaigns offers a feasible solution to eliminate dog-mediated rabies.	[176]
119	Hiby & Tasker (2018)	Bangladesh, Indonesia	Qualitative Study	Stakeholders from Various sectors	Not Specified	Humane dog vaccination combined with capacity building improved rabies control outcomes.	[177]
120	Gibson et al. (2018)	India, Sri Lanka	Implementation study	Dogs population	Not Specified	Mobile apps enabled large-scale vaccination, education, and real-time monitoring.	[69]
121	Ramesh & Pruthvi S (2018)	India	Exploratory study	Dog/cat bite cases	69	Stray dogs caused most bites; incomplete PEP and weak diagnostics persisted.	[178]
122	Tiwari et al. (2018)	India	Cross Sectional Study	Nursing and non-nursing staff	54	Limited RIG availability and staff training gaps hindered effective PEP delivery.	[179]
123	Gautret et al. (2018)	Thailand, Sri Lanka	Observational study	Travelers exposed	Not Specified	Pre-travel rabies vaccination is critical for travelers to endemic regions.	[180]
124	Bharathy & Gunaseelan (2017)	India	Cross Sectional Study	Dog bite victims	Not Specified	Low pet vaccination persisted despite awareness, highlighting gaps between knowledge and practice.	[181]

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S.No	Author(s) (Year)	Country/Region	Study Design	Population	Sample Size	Key Findings	References
125	Brookes et al. (2017)	India	Retrospective Study	Animal rabies cases	Not Specified	Integrated human-animal surveillance is needed for effective rabies control.	[182]
126	Tenzin et al. (2017)	Bhutan	Cross Sectional Study	Town residents	67	Outbreak response showed effective One Health coordination and high PEP uptake.	[183]
127	Silva et al. (2017)	Sri Lanka	Program Evaluation study	Animal Bites Cases	12,121	Digital platforms strengthened real-time rabies surveillance and response.	[53]
128	Holla et al. (2017)	India	Cross Sectional Study	Clinical faculty and postgraduates	Not Specified	Professional and public knowledge gaps limit effective rabies prevention.	[45]
129	Wera et al. (2017)	Indonesia	Cost-Effectiveness Modeling Study	Residents of Flores Island	Not Specified	Cost-effective rabies control relied primarily on sustained mass dog vaccination.	[28]
130	Arief et al. (2017)	Indonesia	Dog survey and Mapping	Owners of owned dogs	Not Specified	Vaccination coverage was high in owned dogs but low in free-roaming and juvenile dogs.	[88]
131	Auplish et al. (2017)	India	Cross Sectional Study	Students	226	Intersectoral school programs improved rabies awareness and bite prevention.	[184]
132	Kazi et al. (2016)	Bangladesh, India	Prospective Study	Cattle, Goats, dog	Not Specified	Low awareness and reliance on traditional healers increased rabies risk despite wound care.	[185]
133	Christiansen et al. (2016)	Thailand	Retrospective Study	Danish travelers	Not Specified	Increase in PEP/PrEP among travelers driven by travel volume, not awareness.	[54]
134	Ghosh et al. (2016)	Bangladesh	Cross Sectional Study	Households	3200	Traditional beliefs and low education hindered effective rabies prevention.	[33]
135	Fitzpatrick et al. (2016)	India	Mathematical modeling study	Dogs and human populations exposed	Not Specified	Mass dog vaccination and education reduced transmission and PEP demand.	[186]
136	Massei et al. (2016)	Nepal	Cross Sectional Study	Free-roaming owned dogs and owners	Not Specified	Low knowledge and dog vaccination rates highlight urgent education needs.	[47]
137	Dhaduk et al. (2016)	India	Cohort study	Animal bite victims	Not Specified	Intradermal vaccination was effective but surveillance gaps remained.	[187]
138	Wera et al. (2016)	Indonesia	Cost-Effectiveness Modeling Study	Dog population	Not Specified	Mass dog vaccination was more cost-effective than PEP alone.	[188]
139	Wera et al. (2016)	Indonesia	Cross Sectional Study	Dog owners	450	Dog-owner education and community participation improved vaccination coverage.	[61]
140	Kularatne et al. (2016)	Sri Lanka	Retrospective descriptive study	Animal exposure cases	19,661	Coordinated One Health strategies improved rabies prevention outcomes.	[89]
141	Rinzin et al. (2016)	Bhutan	Cross Sectional Study	Bhutanese households	Not Specified	CNVR programs achieved high coverage, but responsible ownership enforcement remains essential.	[189]
142	Mani et al. (2016)	India	Retrospective analysis	Patients with suspected human rabies	128	Inadequate PEP, shortages, and weak surveillance contributed to ongoing rabies risk.	[79]
143	Sharma et al. (2016)	India	Cross Sectional Study	Households	500	Urban slums showed awareness but poor wound care and low dog vaccination rates.	[190]

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S.No	Author(s) (Year)	Country/Region	Study Design	Population	Sample Size	Key Findings	References
144	Shankaraiah et al. (2015)	India	Cross Sectional Study	Animal bite victims	Not Specified	Intradermal vaccination improved adherence compared to intramuscular schedules.	[191]
145	Wera et al. (2015)	Indonesia	Cross Sectional Study	Dog owners	Not Specified	Owner education and government leadership supported vaccination success.	[192]
146	Hampson et al. (2015)	Multiple SEA countries	Country Survey	Domestic dog population	Not Specified	Mass dog vaccination is more cost-effective than reliance on human PEP alone.	[193]
147	Craighead et al. (2015)	Sri Lanka	Survey	Street dog	Not Specified	Dog owners showed higher rabies awareness and reporting compared to the general public.	[194]
148	Tenzin et al. (2015)	Bangladesh	Prospective observational study	Free-roaming dogs	Not Specified	CNVR programs successfully integrated vaccination, population control, and community engagement.	[195]
149	Mustiana et al. (2015)	Indonesia	Cross Sectional Study	Dog-owning households and free-roaming dogs	Not Specified	High free-roaming dog populations required owner education and vaccination.	[196]
150	Tenzin et al. (2015)	Bhutan, India	Cross Sectional Study	Free-roaming dogs	Not Specified	CNVR achieved moderate coverage with strong intersectoral support.	[59]
151	Ward & Hernández-Jover (2015)	Indonesia, Timor Leste	Modeling Study	Rabies-free islands and regions	Not Specified	Monitoring dog transport reduced rabies introduction risk in rabies-free islands.	[197]
152	Gibson et al. (2015)	India	Field study	Free-roaming and owned dogs	Not Specified	Smartphone-based monitoring improved coordination of vaccination campaigns.	[198]
153	Kanda et al. (2015)	Sri Lanka	Interventional study	School children	Not Specified	School-based education strengthened community rabies awareness.	[199]
154	Samanta et al. (2015)	India	Prospective Observational Study	Children admitted in hospital	308	Timely PEP was common, but traditional wound care practices persisted.	[34]
155	Digna et al. (2015)	Indonesia	Mixed-methods cross-sectional study	Residents of 10 villages	Not Specified	Community education and mass dog vaccination were central to effective rabies prevention.	[73]
156	Häsler et al. (2014)	Sri Lanka	Case study	Dog and human populations	Not Specified	Vaccinating both owned and unowned dogs was most effective.	[42]
157	Morters et al. (2014)	Indonesia	Longitudinal study	Free-roaming dog populations	Not Specified	Sustained vaccination campaigns increased long-term canine immunity.	[50]
158	Karunanayake et al. (2014)	Sri Lanka	Retrospective Study	Human and animal rabies cases	Not Specified	Free PEP, surveillance, and dog vaccination underpinned rabies control.	[200]
159	Praveen & Kumar (2014)	India	Descriptive study	First-year medical students	90	Medical students showed poor knowledge of rabies PEP, indicating need for better training.	[201]
160	Sittichanbuncha et al. (2014)	Thailand	Retrospective study	Patients	372	PEP followed WHO guidelines; PrEP policies not clearly described.	[202]
161	Raju et al. (2014)	India	Prospective Interventional study	Residents of six villages	Not Specified	Integrated One Health intervention reduced animal bites and rabies risk.	[44]
162	Shridevi et al. (2014)	India	Cross-Sectional Study	Residents of the urban area	Not Specified	Low awareness of dog vaccination; IEC-based education found cost-effective.	[203]

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S.No	Author(s) (Year)	Country/Region	Study Design	Population	Sample Size	Key Findings	References
163	Salve et al. (2014)	India	Observational Study	Patients treated at the ABM clinic	619	Intradermal PEP at primary care was cost-effective but challenged by adherence and vaccine wastage.	[204]
164	Morters et al. (2014)	Indonesia	Prospective Longitudinal Cohort Study	Owned Dogs and Owners	Not Specified	Sustained community-based vaccination and sterilization outperformed culling strategies.	[49]
165	Kashino et al. (2014)	Thailand	Cross Sectional Study	Japanese expatriates and travelers	Not Specified	Traveler PrEP awareness remained critically low.	[205]
166	Mahardika et al. (2014)	Indonesia	Molecular epidemiology study	Rabies-infected humans and dogs	Not Specified	Molecular surveillance enhanced understanding of rabies transmission and control.	[206]
167	Amaral et al. (2014)	Multiple SEA countries	Stratified Sight Survey	Roaming dog	Not Specified	Sight–resight surveys improved dog population estimates for rabies preparedness.	[207]
168	Jain & Jain (2014)	India	Cross Sectional Study	Local residents	Not Specified	Community awareness ensured ARV availability, but first-aid knowledge remained inadequate.	[208]
169	Joseph et al. (2013)	India	Cross Sectional Study	Animal bite victims	200	Low dog vaccination and poor public awareness delayed timely rabies treatment.	[209]
170	Patnaik (2013)	India	Cross-Sectional Study	Animal bite victims	100	Emphasized One Health collaboration, mass dog vaccination, and responsible ownership.	[210]
171	Sridhar et al. (2013)	India	Prospective observational study	Patients with dog bites and rabies complications	54	WHO-recommended PEP with RIG and vaccine was effectively implemented and monitored.	[77]
172	Reece et al. (2013)	India	Retrospective Analysis	Human residents and street dogs	Not Specified	Large-scale sterilization and vaccination effectively reduced rabies risk in urban settings.	[211]
173	Rumana et al. (2013)	Bangladesh	Cross Sectional Study	Adults from five villages	1,973	High awareness but low vaccination due to access barriers and traditional practices.	[212]
174	Belsare & Gompper (2013)	India	Primary Field-Based epidemiological study	Dog populations	Not Specified	Door-to-door and central-point vaccination effectively controlled rabies.	[80]
175	Sibunruang et al. (2013)	Thailand	Retrospective observational study	Travelers	Not Specified	Traveler education is essential in endemic rabies regions.	[213]
176	Putra et al. (2013)	Indonesia	Retrospective Study	Dog and human populations in Bali	Not Specified	Integrated One Health strategies improved rabies control in Bali.	[214]
177	Wera et al. (2013)	Indonesia	Cost-Effectiveness Modeling Study	Dog and human populations	Not Specified	Integrated mass dog vaccination, human prophylaxis, and education strengthened rabies control.	[215]
178	Hossain et al. (2013)	Bangladesh	Cross Sectional Study	Dog population	Not Specified	Accurate dog population counts were essential for rabies planning.	[216]