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Review Article

# Quadripartite Vision and Mission of Dog-Mediated Rabies Elimination: Cross Border Transmission Threats

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**Abstract**: Dog-mediated rabies is an evident global health problem due to the transmission of bite injuries inflicted by free-roaming dogs in developing countries. More than 95% of human rabies cases are happening due to free-roaming dogs. The World Organization for Animal Health, World Health Organization, Global Alliance for the Control of Rabies, and the Food and Agriculture Organization of the United Nations jointly signed the agenda and mission to eliminate dog-mediated human rabies by the end of 2030. The vision has been set to combat this oldest recorded infectious disease of mankind, but it seeks serious commitment, planning, and investment in the developing countries of Asia and Africa where the legislative involvement and overhead support of their respective government are already deficient. Variable challenges to attain this vision in diverse countries exist, and one of the major issues is the cross-border transmission risks of circulating strains of rabies viruses through animal reservoirs and trades. The present review article has been designed to investigate the global purposes and motives of various activities and working groups of the quadripartite and the United Against Rabies (UAR) forum with a special focus on developing countries and the existing One Health approach. Moreover, various strains and risk factors of rabies virus at cross-regional borders have also been highlighted by searching articles through various online databases such as Google Scholar, PubMed, ScienceDirect, and Google. A well-designed surveillance system and support from the governments may foster this challenging mission of the quadripartite.

**Keywords:** Cross-border, Dog-mediated rabies, One Health, Quadripartite, Risk factors.

## 1. INTRODUCTION

The rabies virus (RABV), a severe infectious disease of public health importance, causes the contagious zoonotic disease in humans by the bite of a dog which is commonly known as dog-mediated rabies [1]. The most frequent way that dog-mediated rabies spreads and causes injuries to humans and animals is mostly by free-roaming dogs and infrequently by wild animals in Asia and Africa [1, 2]. Rabies can be prevented before symptoms appear, but it is nearly difficult once the clinical symptoms appear. Therefore, raising public awareness of dog-bite injuries to humans is crucial. The World Health Organization (WHO) classifies rabies as one of the neglected tropical diseases [3]. Despite having a disease that is curable by vaccine, the most recent estimate of annual human rabies deaths from a 2015 study is as high as 59,000 across 150 countries [4]. Dog-bite injuries account for more than 95% of human rabies infections, making the elimination of dog-mediated rabies a

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global priority [5]. In order to completely eradicate dog-mediated rabies by the year 2030, the WHO, World Organization for Animal Health (WOAH), the Food and Agriculture Organization (FAO) of the United Nations, and the Global Alliance for Rabies Control (GARC) have jointly proposed the One Health framework [3].

By bringing together these four essential stakeholders, the quadripartite approach leverages their respective capabilities to create a more comprehensive and effective strategy for dog-mediated rabies elimination. Collaboration enables the pooling of resources, knowledge, and experience to tackle this complex challenge [6]. Dog-mediated rabies elimination requires a multifaceted approach that involves the solutions present in human health, animal health, and environmental health sectors at national levels of the countries. The quadripartite approach ensures that experts from various fields work together to address the complexity of dog-mediated rabies transmission [7]. Rabies knows no borders, and cross-border transmission threats are a significant concern for molecular epidemiologists and phylogenetic studies. The quadripartite approach acknowledges the need for international cooperation to prevent the spread of dog-mediated rabies, making it a bold global issue [8].

To protect both humans and animals from dog-mediated rabies, the One Health approach's strategy is crucial [9]. One Health is a fusion of three distinct fields: environmental sciences, veterinary medicine, and public health [9]. This approach enables cooperation among the major global organizations which are strong advocates of human, and animal health and the environmental ecosystem. To protect both humans and animals from dog-mediated rabies, this strategy's primary goal is to raise people's understanding regarding disease control, prevention, and treatment [10].

According to the vision of the quadripartite organizations, [11] insightful information on the economics of dog-mediated rabies is important to consider while planning disease control programs and these organizations also provided crucial advice for the program orientation. Similarly, these organizations updated their assessment of the dog-mediated rabies burden in Asia and Africa and provided new insight into the disease's effects on these continents [12]. A case study on rabies in the Serengeti environment was also carried out to study the dog-mediated rabies reservoirs, which explored reservoir dynamics and advanced our knowledge of the disease's intricacies [13]. In this article, various credible research studies were examined to investigate the visionary guidelines of the quadripartite and how cross-border transmission of dog-mediated rabies has influenced this vision and mission. The extracted studies pertaining to the objectives of the articles were categorized into various subheadings to discuss and elaborate the mission of the quadripartite. Moreover, the cross-border transmission of dog-mediated rabies virus also threatens this mission and few logical studies also describe details regarding the border-based transmission pattern of the rabies virus strains.

Various keywords and Boolean operators were used to include credible research papers from the journals that align with the objective of the paper, while predatory and web-based resources were excluded. Moreover, articles in languages other than English were also excluded.

## 2. RABIES THREATENS GLOBAL HEALTH

The impact of dog-mediated rabies is worldwide and most commonly it is present in Asia and Africa. The RABV affects thousands of people and animals in underdeveloped and marginalized countries Figure 1. Besides these, the RABV is the major

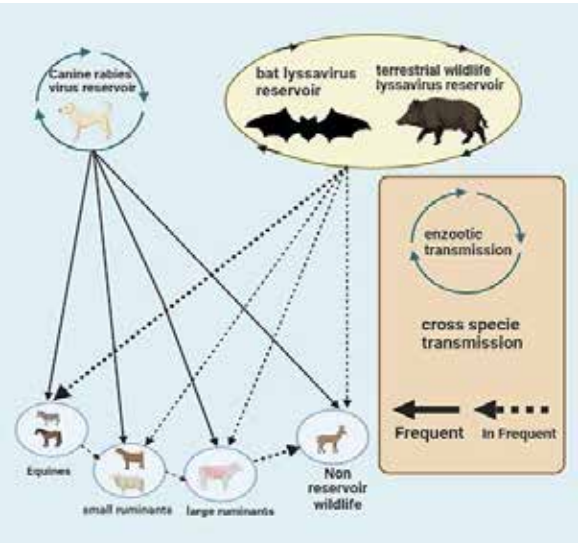


**Fig. 1.** Diagram showing various food and wild animal reservoirs that frequently and infrequently facilitate the cross-species transmission of RABV that potentially play a role in the cross-border transmission of the RABV.

cause of animal deaths across the world [14]. Therefore, we can't be able to help and grow the livestock sector because we are spending the budget on zoonotic diseases treatment and prevention [15].

Several zoonotic diseases clearly show the dire need for a One Health approach to solve the problems infecting humans, animals, and the environment [16]. Dog-mediated rabies is also one of these deadly diseases that demands collaboration like quadripartite to control disease or prevent disease at the human-animal interface due to the complex nature of the disease dynamics [17]. Similarly, the changes in environmental conditions sometimes may cause changes in morbidity, mortality, and disability adjusted life year score (DALYs) among humans and animals of various geographical regions in the developing world [18].

To successfully manage and prevent zoonotic illnesses like rabies, the links between human, animal, and environmental health must be understood and addressed [19]. We can enhance global health outcomes and defend both human and animal populations by putting One Health concepts into practice including coordinated surveillance, early identification, and quick response to disease outbreaks [20].

## 3. THE NEED OF QUADRIPARTITE

The quadripartite purpose is to realize that the 'Rabies 0 by 30' vision, supports the Sustainable Developmental Goals (SDGs) such as 'Good Health and Well-Being', Reduce Poverty, and 'Life on Land' [21]. The quadripartite approach acknowledges the need for international cooperation to prevent the spread of dog-mediated rabies, making it a global issue [22]. By eliminating dog-mediated rabies, the quadripartite initiative contributes to the improvement of public health. It reduces the burden on healthcare systems, saves lives, and enhances the well-being of communities affected by rabies [23]. Dog-mediated rabies has ecological implications as well. The vaccination and control of rabies in dogs help protect wildlife and preserve biodiversity, aligning with the goal of sustainable land use and conservation [24].

The quadripartite method, with its emphasis on dog-mediated rabies elimination, not only helps to save human lives, but also advances animal welfare, environmental protection, and public health [25]. It will result in better ecosystems, healthier communities, and a critical step towards reaching sustainability and global health goals [26]. The quadripartite vision and mission of dog-mediated rabies elimination represents a united effort to combat rabies. By bringing together government health agencies, veterinary authorities, and international partners, this collaborative approach aims to eliminate rabies and make the world safer for both humans and animals [27]. This initiative holds great promise for the future, aligning with sustainable developmental goals and benefiting the global community [23].

## 4. UNITED AGAINST RABIES (UAR) FORUM

The United Against Rabies (UAR) forum stands as a vital global initiative aimed at rallying stakeholders from a diverse array of sectors to collectively combat rabies [28]. Established with a common vision for the global elimination of this deadly disease, the UAR forum serves as a platform that fosters collaboration and coordination to accelerate progress toward a rabies-free world [26]. One of the primary strengths of the UAR forum is its inclusivity. It brings together stakeholders from a wide range of sectors, including public health, veterinary medicine, government agencies, international organizations, non-governmental organizations (NGOs), and private industries of the developing world. This diverse coalition of partners ensures that various perspectives and expertise contribute to the fight against rabies [25].

The cornerstone of the UAR forum is a shared vision: the global elimination of dog-mediated rabies. This common goal unites participants and provides a clear direction for their collective efforts [25]. The UAR forum operates under the overarching objective of achieving '0 by 30' which aims to eliminate human deaths from dog-mediated rabies by the year 2030. This ambitious target is a testament to the commitment of all stakeholders involved [29]. To effectively address the multifaceted challenges associated with dog-mediated rabies, the UAR forum establishes topic-specific working groups. These groups focus on various aspects of rabies control and elimination, including vaccination strategies, surveillance, community engagement, policy, and research. By concentrating efforts in these specific areas, the UAR forum can make significant progress in

a coordinated manner and facilitate the 0 by 30 mission of the quadripartite [30].

One of the core missions of the UAR forum is to support and enhance the progress towards the '0 by 30' vision. This involves developing and implementing comprehensive strategies to eliminate dog-mediated rabies [25]. The UAR forum provides a platform for sharing best practices, coordinating resources, and advocating for the importance of rabies elimination on a global scale [31]. The health priorities of the G20, particularly those highlighted during the recent India-G20 summit, are closely connected to the goals of the UAR forum [32]. One of the priorities emphasized during the summit is 'Building resilient systems for health emergency prevention, preparedness, and response [33]. The UAR forum's efforts to eliminate rabies align with this priority by strengthening health systems and emergency preparedness, as rabies is indeed a significant health emergency that can be prevented through effective mass dog vaccination programs and control programs [34].

The UAR forum represents a collaborative global effort to eliminate dog-mediated rabies, uniting stakeholders from diverse sectors with a common vision [31]. Through the establishment of working groups in this forum, support for the '0 by 30' initiative, and alignment with G20 health priorities, have been justified to benefit the health of communities worldwide [35].

## 5. MASS DOG VACCINATION: A MISSION OF QUADRIPARTITE

The most important and crucial aspect in preventing dog-mediated rabies and other zoonotic diseases is the vaccination of animals and humans [18]. Because vaccinating animals breaks the transmission bond between animals and humans [36]. Similarly, the vaccination of health care workers (especially veterinary doctors and vaccination team workers) helps us to protect their lives. Therefore, it is very important to work together in preventing the spread of dog-mediated rabies and make sure the vaccination of animals and humans have been well planned [37].

In addition to rabies, implementing preventive measures and management techniques is crucial to control dog-mediated rabies. Due to the public's ignorance regarding knowledge of dog-mediated rabies, organizing awareness programs and seminars is also crucial [18]. The diagnosis of dog-mediated rabies is the other crucial element in this regard. The early detection of the illness enables us to stop new cases from occurring in the future [38]. As a result, keeping an effective surveillance network on affected animals and people on a regular basis aids in the further contact tracing of the diseased animals [39].

We can make all these immunization campaigns and one-health prevention initiatives successful if veterinary healthcare experts and human health professionals collaborate well on identified gray areas [40]. Specialists in veterinary medicine have key responsibilities in the diagnosis, treatment, and prevention of animal cases, and their close collaboration with medical health experts helps to prevent human infection [41]. We can expand this cooperation by establishing programs for data sharing, and the One Health approaches to rabies control will lead to more effective coordination and communication at regional, national, and global levels [10].

## 6. CHALLENGES AND ROADBLOCKS IN 0 BY 30 MISSION

An increasingly serious threat is being presented by dog-mediated rabies. Unfortunately, it has imparted negative effects on the social and economic conditions of entire nations, in addition to the animal species, the effects of this deadly disease's spread are catastrophic, putting a heavy financial load on both governments and communities Figure 2. Budgets for healthcare are already severely constrained, and the expenses associated with vaccination campaigns, post-exposure prophylaxis, and animal control activities are extremely burdensome [42].

Additionally, the death toll from dog-mediated rabies has had a significant impact on our livestock business, particularly in rural areas where people rely largely on these animals for their livelihoods [43].

The One Health strategy must be implemented in all countries, despite numerous obstacles. For instance, it can be extremely challenging at times to vaccinate all the animals due to financial and social issues [44]. The inability to vaccinate every animal poses a limitation and a resource shortage as well

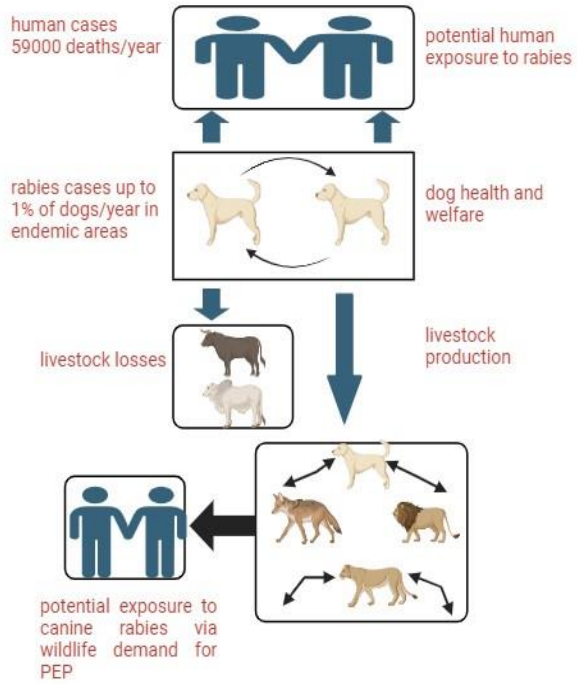


**Fig. 2.** Impact of dog-mediated rabies on dog, food animals, and human deaths that occur due to suspected dog bite injuries. The dog-mediated rabies can also be transmitted to wild animals which again infect humans

[6]. In addition, cultural practices and beliefs that prevent people from immunizing their pets are a significant barrier [15]. The issue at hand is how to get past these obstacles. By increasing social funding for these people, we can remove these obstacles and inform them about the horrifying clinical pictures of forthcoming events due to dog-mediated rabies.

## 7. CROSS-BORDER TRANSMISSION THREATS OF DOG-MEDIATED RABIES

Rabies is a viral disease that knows no borders, and its elimination requires global efforts [45]. Cross-border transmission threats play a significant role in perpetuating the disease, making collaborative strategies essential. Several factors contribute to these threats, each with its unique challenges and implications[46]. Illegal cross-border trade in animals, particularly dogs, can introduce dog-mediated rabies into non-endemic regions [47]. This challenge emphasizes the importance of stringent border controls and regulations to prevent the illegal movement of animals[48]. Travelers visiting rabies-endemic regions may be at risk of exposure. Promoting rabies awareness and pre-travel vaccination is crucial for travelers to mitigate this risk [49]. Disparities in vaccination coverage between neighboring countries can create pockets of susceptibility near borders. Collaboration and harmonization of vaccination programs across borders are essential to achieve consistent protection [50].

Wildlife reservoirs can contribute to the perpetuation of dog-mediated rabies, especially in areas with extensive land borders [51]. Enhanced surveillance and control measures targeting wildlife populations are needed to prevent spillover to domestic animals and humans [52]. Difficulties in accessing and sharing canine vaccination data and dog bite registries across national borders hinder effective disease monitoring and response [53]. Improved data-sharing mechanisms and international cooperation are essential to track and control dog-mediated rabies [54].

Discrepancies in dog population size estimates or censuses across borders can complicate vaccination planning. Standardized methodologies for estimating dog populations and data sharing are critical for effective vaccination campaigns [55]. The trade-in of dogs and cats for meat can facilitate the movement of potentially rabid animals. Strict regulations and enforcement regarding the trade of these animals are necessary to reduce transmission risks[56].

The pet trade, particularly unregulated and informal breeding and sales activities, can introduce rabid animals across borders. Strengthening regulations and promoting responsible pet ownership can mitigate this threat [56]. Cross-border migrants may face challenges in accessing post-exposure prophylaxis (PEP) in a timely manner [46]. Ensuring equitable access to PEP for all individuals, including migrants, is crucial[45]. The absence of robust surveillance and monitoring systems can impede early detection and response to rabies cases [57]. Investment in surveillance infrastructure and capacity-building is vital for effective control [58].

Gaps in the endeavor to control dog-mediated rabies can be caused by variations in response techniques across borders [59]. For a united approach, coordinating epidemic responses and harmonizing response methods are crucial [60].

The need for global cooperation in tackling these concerns of cross-border transmission cannot be overstated. To achieve the global aim of eradicating dog-mediated rabies by 2030, cooperative efforts, standardized practices, and information exchange are essential [61].

## 8. QUADRIPARTITE AT THE POLICY LEVEL

Effective lobbying for the One Health approach at the policy level is required to include factors for the health of people, animals, and the environment in complete policies. By adopting One Health laws and regulations, policymakers can promote collaboration amongst many sectors and enhance efforts at disease surveillance, prevention, and response. This approach has gained popularity since it is effective in addressing challenging health concerns [62]. By highlighting the interdependence of human, animal, and environmental health in policy frameworks, resources can be allocated more successfully and disease patterns can be understood better [63]. Through this advocacy, decision-makers can promote all-encompassing and long-lasting solutions to public health problems, such as the control of zoonotic diseases like rabies.

It is essential to translate One Health advocacy into real rules and regulations to address global health challenges and prevent zoonotic disease outbreaks successfully. Governments, public health agencies, veterinary organizations, and environmental departments must work together to implement the One Health policy framework through legislative ordinance [64]. Such policies can include coordinated disease control strategies, cross-sectoral coordination mechanisms, and combined surveillance and reporting systems. Countries can promote the flow of important information and data sharing by harmonizing legislative frameworks and standardizing methods [65]. Utilizing technology and innovation to improve infectious disease monitoring and response skills is another aspect of putting One Health policy into practice [66].

Adequate financing and resources are needed to support research, surveillance systems, and capacity-building efforts to sustain the One Health project. Stakeholders can promote the application of One Health policies by arguing for additional financial assistance from governments, international organizations, and the corporate sector [67]. Innovations in disease prevention, diagnostics, and control strategies can result from securing funding for cross-sectoral collaborations and collaborative research [68]. Additionally, pushing for specialized financing sources for One Health initiatives can guarantee sustained commitment to the cause [69]. Advocates can get the required funding to effectively tackle rising health dangers by convincing politicians of the cost-effectiveness and societal advantages of One Health solutions.

Governments, non-governmental organizations, academia, and international organizations must work together effectively on a global scale for One Health projects to be successful [70]. Collaborative tools can make it easier to share knowledge, best practices, and insights from fruitful One Health initiatives [71]. Stakeholders can access a wide range of expertise, pool resources, and work together to address global health concerns by developing international partnerships [72]. As early warning systems are supported by international cooperation, prospective disease outbreaks can be addressed quickly [73]. Additionally, collaborations with the business sector and industry stakeholders can spur advancements in disease prevention strategies, surveillance technology, and vaccine research [74].

## 9. FACILITATIONS IN ONE HEALTH COMPETENCY SUSTAIN THE MISSIONS OF QUADRIPARTITE

When utilizing the One Health idea, interdisciplinary research is crucial to address complicated health concerns like rabies prevention and control. By bringing together experts from several fields, such as human and veterinary medicine, epidemiology, ecology, and environmental scientists, the researchers can get comprehensive insights into the dynamics of dog-mediated rabies [75]. Cooperative research initiatives have aided the creation of innovative solutions and the understanding of transmission routes [76]. Those nations who have relatively controlled dog-mediated rabies such as India, Sri Lanka, Philippine, and Thailand have an understanding of the importance of the connections between human, animal, and environmental health. These connections have been improved by this interdisciplinary study which also makes it simpler to develop evidence-based preventative strategies for zoonotic diseases like rabies [77].

Collaboration across many stakeholders,

including public health agencies, veterinary services, wildlife conservationists, and local populations is essential for effective rabies prevention and control [78]. These many organizations can pool their knowledge, resources, and experience through collaborative studies to develop comprehensive methods that are adapted to certain situations [63]. These may include vaccination efforts for both domestic animals and wildlife, as well as community outreach initiatives to encourage responsible pet ownership and raise knowledge of rabies transmission [79]. Together, these parties can develop sustainable and comprehensive rabies management strategies, thereby easing the burden of this grave global health concern.

Powerful techniques for enhancing rabies surveillance and monitoring activities have been made available through technological improvement [80]. Maps of high-risk locations and probable disease hotspots can be created using remote sensing, Geographic Information Systems, artificial intelligence, and big data analytics [81]. Furthermore, mobile applications and real-time reporting platforms can improve disease surveillance in both human and animal populations, helping the early identification of suspected cases in animals and humans. The ability to quickly and accurately identify rabies strains is also made possible by developments in molecular diagnostics and viral genomes, aiding in epidemic investigations and tracing disease transmission pathways [82]. Public health officials and researchers can improve their capacity to spontaneously predict and react to new rabies outbreaks by utilizing technology-based disease detection tools [83].

The effectiveness of One Health's efforts in rabies prevention depends on fostering a culture of knowledge-sharing and cooperation [84]. Platforms to exchange research results, best practices, and lessons learned to encourage collaboration among stakeholders at the local, national, and international levels need to be explored and implemented [85]. Researchers, practitioners, and policymakers can communicate on shared initiatives including international conferences, workshops, and online networks [86]. By developing a common knowledge base, the international community can take advantage of one another's failures and triumphs to enhance rabies prevention and control methods throughout time which will get nations one step closer to reliable success.

## 10. ENGAGING THE COMMUNITY: ONE HEALTH EDUCATION AND EMPOWERMENT

We can spread correct information about illness prevention and the significance of ethical pet keeping by supporting public awareness initiatives and educational programs. Communities are better able to protect themselves and their cherished animals when they are informed about the dangers of rabies transmission and the advantages of vaccination. Various platforms may be used to carry out public awareness campaigns, ensuring that information reaches a variety of groups and distant locations where the disease burden may be high. The prevention and management of dog-mediated rabies depend greatly on public education. Communities must be informed about the dangers of rabies transmission, the value of responsible pet ownership, and the advantages of vaccination if they are to adopt a proactive approach to disease prevention [87]. To spread accurate and understandable information about rabies, public health campaigns can make use of a variety of communication platforms, including social media, radio, and community workshops [88]. By raising public knowledge of rabies prevention, communities may decide for themselves whether to report probable rabies cases, participate in vaccination programs, and seek prompt medical attention for animal attacks.

Successful One Health projects require strong community participation and engagement. The success and viability of such programs are improved when communities are given the tools they need to actively participate in zoonotic disease surveillance, prevention, and control activities [89]. One Health project such as the UAR forum progress and vision of the quadripartite can target unique community needs and personalize treatments by incorporating local community leaders, healthcare practitioners, veterinarians, and environmentalists in decision-making processes [90]. Through collaborative initiatives that promote ownership and accountability within the community and capacity-building seminars, training sessions, and projects, empowerment may be attained [91]. Participating in One Health projects helps communities become more resilient to disease outbreaks and fosters a feeling of shared accountability for preserving the health of people, animals, and the environment.

It is essential to develop the upcoming generation of activists and experts as One Health continues to develop. The interdependence of human, animal, and environmental health may be effectively promoted by educational institutions [92]. Future professionals can develop a multidisciplinary perspective by incorporating One Health principles into academic curricula, veterinary and medical training, and environmental research [93]. Students may also be motivated to pursue jobs in sectors connected to One Health through research opportunities and mentoring programs [93].

## 11. CONCLUSIONS

In the context of zoonotic illnesses like rabies, the idea of One Health has emerged as a potent and crucial strategy for solving complicated health concerns. One Health enables us to take a comprehensive approach to the prevention and control of animal-originated diseases and epidemics. Group efforts and collaborations are essential for assuring a safer and healthier future as we become more alert of how closely bordered countries and interrelated human, animal, and environmental health are at risk of contracting an emerging or remerging disease from nowhere.

Rabies continues to be a serious worldwide health issue, especially in areas with poor resources and access to healthcare. We all have a responsibility to actively contribute to rabies prevention initiatives, both as an individual and as a community. Furthermore, promoting the adoption of One Health techniques at the policy level can lead to a considerable shift in disease surveillance, preventive, and control methods. For the One Health goal to be advanced and emerging illnesses like rabies to be properly combated, ongoing research and innovation are essential. For identifying gaps and creating evidence-based solutions, scientific research on disease transmission, monitoring, and control techniques is crucial. We can improve disease surveillance, provide effective diagnostic tools, and track disease outbreaks in real time by using technology and transdisciplinary research. Additionally, funding studies to learn more about how disease transmission is impacted by climate change may help us to proactively address changing health concerns. We improve our readiness and response capacities via ongoing research and innovation, creating a more robust global health system.

One Health stands for a uniting force that cuts beyond distinctions and unites people, communities, and organizations in the quest for the health and well-being of all and the quadripartite is a real-time example in front of us. We have the chance to build a future that is safer, healthier, and more sustainable for both people and animals if we embrace the One Health principles, then active participation, public awareness, and dedication to research and innovation are all requirements of this approach that should be carried out in rabies endemic countries. Together, we can protect the well-being of our neighborhoods and maintain the precarious equilibrium between people, animals, and the environment for future generations.

## 12. CONFLICT OF INTERESTS

The authors declared no conflict of interest.

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