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Review article

RABIES: UNITING FOR ONE HEALTH - PROTECTING HUMANS AND ANIMALS TOGETHER

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Abstract: *This review article elucidates the intricate dynamics of rabies and its effects in the context of a persistent global threat using the One Health approach. This article emphasizes the inescapable link between human, animal, and environmental health by clarifying the complex mechanisms of rabies transmission, elaborating on its symptoms and course, and demonstrating its global occurrence and impact. This article highlights the crucial importance of zoonotic diseases, notably the reservoir role of animals in rabies transmission, and embraces the idea of One Health, which recognizes the symbiotic interactions between these domains. This study highlights the significance of unified control and surveillance systems from a strategic perspective. This emphasizes the value of vaccination as a cornerstone for safeguarding both human and animal populations. Additionally, it highlights the potential of interdisciplinary One Health initiatives to eradicate rabies through successful case studies. This article sheds light on the crucial role of international organizations, the significance of policy advocacy, strict regulation, and international cooperation while addressing socioeconomic consequences, implementation challenges, and the goals of a rabies-free world. Interdisciplinary research has emerged as a catalyst to develop innovative prevention and control methods that are strengthened by technology, shared knowledge, and resilient strategies to combat the effects of climate change and emerging diseases. Public engagement, education, and community empowerment should be implemented to establish a proactive approach to rabies prevention. It concludes with a loud appeal for coordinated One Health initiatives to build a safer future in the face of this ongoing issue.*

Keywords: Global Collaboration, One Health, Rabies, Vaccination, Zoonotic Diseases

1. Introduction

The contagious zoonotic disease rabies is caused by the rabies virus, which poses a severe risk to public health worldwide (1). Figure 1 depicts how dogs, cats, and other wild animals are the most common carriers of rabies and are the primary sources of skin bites and scratches (2). Rabies can be controlled before symptoms appear, but it is almost impossible once they do. Therefore, informing people about rabies transmission and increasing public awareness of dog bites is critical (3).

One Health strategy is essential for preventing rabies in both humans and animals. According to, one Health discipline is the merging of three different disciplines: environmental sciences, veterinary medicine, and public health(4). One Health center is also in charge of coordinating the efforts of these three disciplines. The fundamental objective of this strategy is to increase public awareness of disease control, prevention, and treatment to protect both humans and animals from rabies (5).

In their analysis, (6) Provided essential guidance for program orientation and valuable information on the economics of eliminating canine and human rabies. The rabies burden in Asia and Africa was also updated in (7), offering fresh information on the impact of the illness on these continents (8). A case study on rabies in the Serengeti ecosystem was also conducted, which studied reservoir dynamics and increased our understanding of the disease's subtleties.

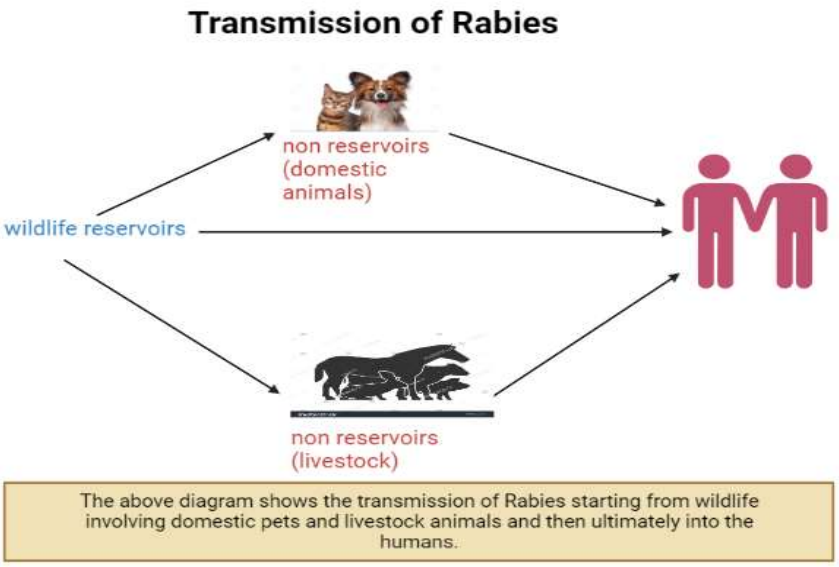
2. The Rabies Virus: A Lethal Threat

Rabies is a fatal virus-based disease. Dog bites or scratches on the skin are other important causes. It can also be spread through the saliva of affected animals. (9). When we talk about the predilection site of rabies, the brain shows symptoms. The rabies virus takes almost two to three weeks to show its full symptoms (10). Rabies is an illness that exhibits delayed signs. As the disease progresses, infected humans and animals may experience agitation, anxiety,

excessive salivation, and hallucinations. Rabies symptoms initially include flu-like symptoms, headache, and fever (9). The end-stage rabies causes paralysis and respiratory failure, ultimately leading to death. (10).

The effects of rabies are felt worldwide, although Asia and Africa are the most frequently affected (11). Figure 2 illustrates how the rabies virus primarily affects .

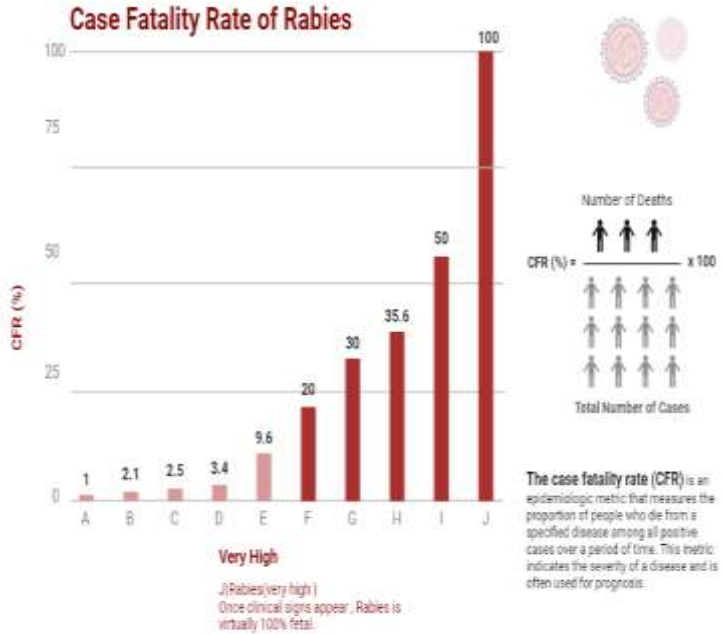
underdeveloped nations and millions of humans and animals worldwide. In addition, the rabies virus is the leading cause of animal deaths worldwide. As we spend a budget on the treatment and prevention of zoonotic illnesses, we are unable to assist in or grow the livestock industry. (12)



.Fig. 1. The above diagram shows the transmission of rabies starting from wildlife involving domestic pets and livestock animals and then ultimately into the humans.

3. The One Health Concept

One Health strategy connects human health, animal health, and the environment. One Health states that human, animal, and environmental health depend on each other, and a change in one will cause a change in the other, as shown in Figure 3(13)



. **Fig.2. The above graph is showing the case fatality rate of rabies and other diseases**

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We also cover how the three fields of human health, veterinary medicine, and environmental sciences might work under a One Health umbrella. In managing urgent circumstances worldwide, the efficiency of all these organizations is crucial.(14).

The One Health concept, which links people, animals, and the environment, is evident in numerous current zoonotic diseases. Rabies is one of the diseases that illustrates how these three sectors work together to prevent the spread of diseases or reduce their severity.(15). Zoonotic viruses can spread from humans to animals owing to the ability of zoonotic diseases to spread between animals and humans and occasionally in the opposite direction. Similarly, changes in environmental circumstances can occasionally spread numerous diseases that harm humans and animals.

Understanding and addressing the connections between human, animal, and environmental health is necessary to manage and prevent zoonotic diseases such as rabies effectively. (16)Implementing the One Health principle, such as coordinated surveillance, early identification, and swift response to disease outbreaks, can improve global health outcomes and save human and animal populations.(17).

4. Rabies, wildlife and One Health: An Unbreakable Bond

Rabies is a zoonotic disease that can spread from animals to humans and occasionally from humans to other animals. This disease transmission amply demonstrates the connection between humans and animals. (18, 19)Dog bites have already been mentioned as the leading cause of rabies, but the disease can occasionally spread through other animal secretions, particularly saliva. (20). However, if we are aware of rabies transmission mechanisms, human and animal cases can be avoided. One Health philosophy is crucial in this regard. (21).

Zoonotic diseases can quickly spread from animals to humans. Rabies is also a zoonotic disease that damages both animals and humans. (22). Zoonotic diseases do not require direct contact with humans to spread, but they are first transferred to dogs, cats, and other wildlife and domesticated animals and then into humans by direct contact or by exposure to the environment, as shown in Figure 1 (23, 24).

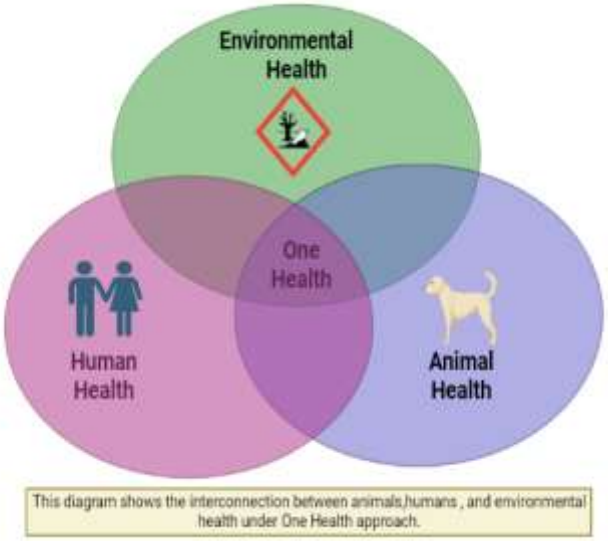

Fig. 3. Diagram showing the interconnection between animals, humans, and environmental health under One Health

A single factor does not spread diseases such as rabies, but a multidisciplinary approach is responsible for spreading rabies-like diseases. Therefore, one health approach is critical, one that interlinks all three sectors and ensures the collaboration of all three sectors to prevent such zoonotic diseases.(25).

Wild animals also play a significant role in transmitting rabies, along with dog and cat bites. Rabies can only be transported from one place to another with the help of a reservoir host such as humans.(26). Dogs and cats can contract it using wild animals, the most common hosts. Diseases can spread to humans because we maintain dogs and cats as pets in our homes and because we have direct contact with them. (18). Thus, we must control this disease in wildlife to safeguard human life. To combat rabies, a health policy emphasizes the value of wildlife animals.(19).

5. One Health Strategies for Rabies Prevention

Immunization of humans and animals is the most significant factor in preventing rabies and other zoonotic diseases. (19). Knowing that dogs and cats are the primary hosts of the rabies virus will help prevent and ultimately eradicate rabies from the planet.(27). Vaccination disrupts the relationship between animals and people. Similar to how it helps preserve patients' lives, vaccinations for medical personnel, particularly veterinarians and other staff members, are essential. As a result, everyone must work together to eradicate rabies from the planet and ensure that both humans and animals receive the necessary vaccinations.(28).

Figure 4 illustrates the importance of implementing management strategies and preventive actions to control rabies.

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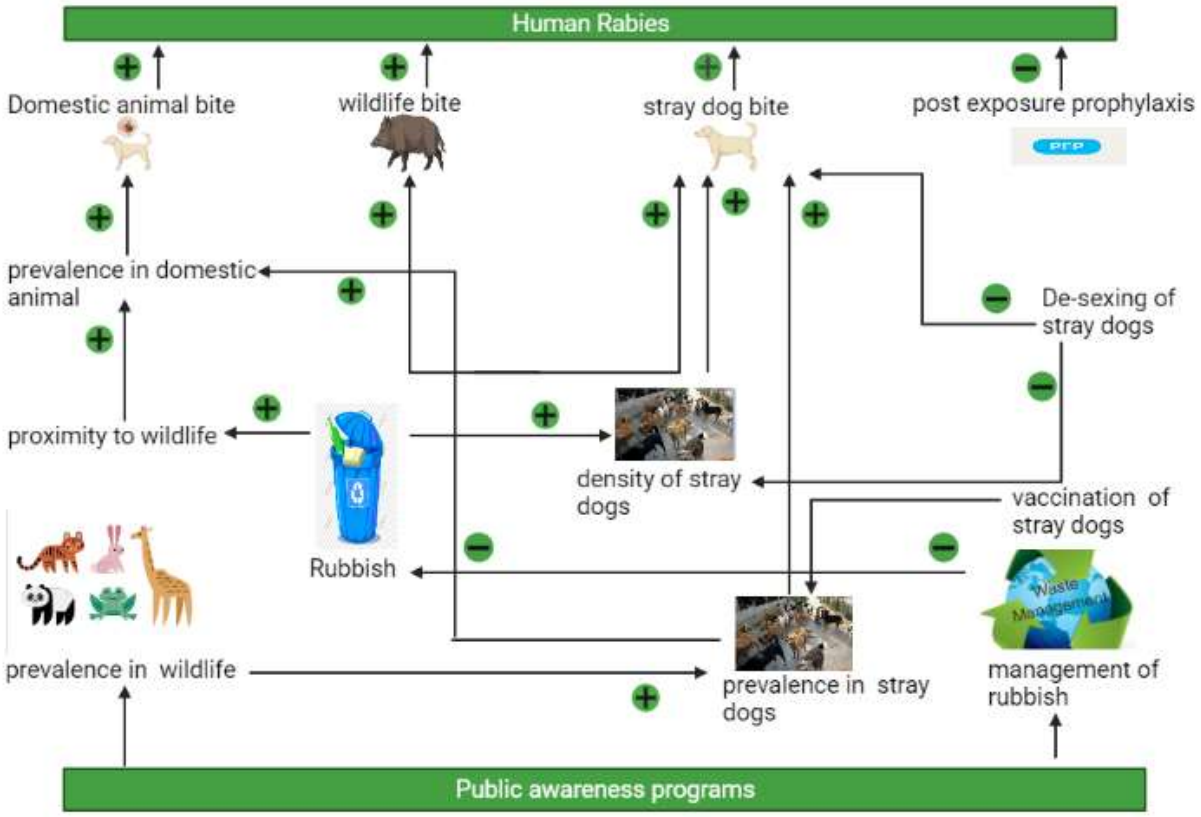

Fig. 4. Diagram showing the One Health Approach to control rabies.

Organizing awareness programs and seminars is essential because the general public is ignorant of rabies. (19). Another critical factor is rabies diagnosis. By identifying sickness early, we can prevent further cases from emerging.(29). To further diagnose the condition, break the link between animals and people, and ultimately eradicate rabies, it is necessary to regularly monitor infected animals and people and note any changes in their symptoms.(25).

If animal healthcare specialists and human health professionals work closely together, we can make all these immunization programs and one-health preventative activities successful. (30)Veterinary medicine specialists diagnose, treat, and prevent animal illness. They work closely with medical health professionals to reduce the risk of human infection.(31). By establishing programs for data sharing, cooperation can be increased, and the One Health approach to rabies control will benefit from efficient coordination and communication.(5).

6. Success Stories: Eliminating Rabies Through One Health

Eradication of the rabies virus from this planet is possible through the cooperation of veterinary and public health professionals, which is one health approach. In regions where it is incredibly challenging to eradicate rabies, much success has been accomplished under one health strategy. The effectiveness of community engagement is demonstrated through success stories and cases. One health approach has ended the transmission cycle between animals and humans through effective vaccination campaigns and awareness seminars. In addition to vaccination campaigns and awareness programs, community involvement, pet owners' accountability, prompt reporting of cases to authorities, and diagnosis have all been essential factors in rabies control. Therefore, success stories show successful work under the one-health approach to protecting humans and animals. (32).

7. Challenges and Roadblocks

Rabies, a zoonotic disease that kills dogs, cats, and wild animals worldwide, poses an increasingly severe threat.(33). In addition to animal species, it has terrible repercussions on all countries' social and economic climate. The spread of this fatal disease has disastrous consequences, costing both governments and communities a lot of money.(34). The costs involved in vaccine campaigns, post-exposure prophylaxis, and animal control initiatives are considerable and extremely taxing, and healthcare budgets are severely constrained.(35). The number of rabies fatalities has also substantially impacted our livestock business, especially in rural areas, where people rely heavily on these animals for their livelihoods. (36).

There are many challenges; however, every country must apply the same health plan. For instance, as illustrated in Figure 5, vaccinating all animals might be difficult due to financial and social concerns (16).

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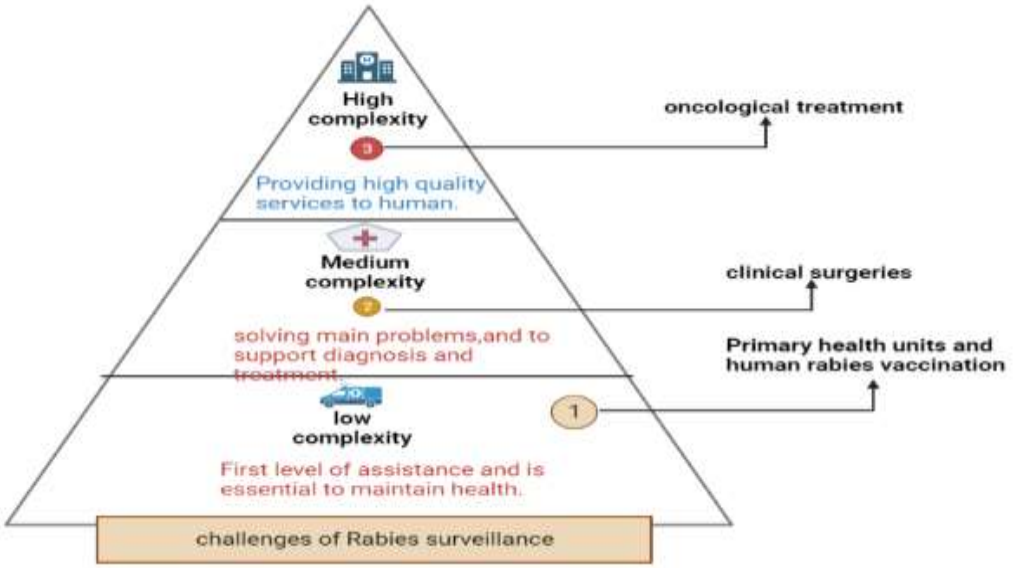

Fig. 5. Diagram showing various challenges of rabies surveillance.

Lack of resources and limitations result from the inability to vaccinate every animal (37). Cultural customs and beliefs prohibiting pet vaccinations pose considerable obstacles (12). We may overcome these challenges and educate them about lethal zoonotic diseases known as rabies by improving social funding and communicating with them(38).

8. Future Prospects and Global Cooperation

We can confidently assert that rabies no longer threatens the world. Due to the solid one-health strategy, which includes vaccination campaigns, awareness seminars, and programs, and the involvement of communities, all three sectors, including those in human health, veterinary medicine, and environmental sciences, have collaborated. Nevertheless, it can be found in a few places, particularly in Africa and Asia. (39). Thus, if we cooperate and work with veterinary specialists, medical professionals, and the field of environmental sciences in the future, we will be wholly protected from rabies, as shown in Figure 6. We must contribute financially to medical research to protect ourselves against rabies in the future (40)

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Fig. 6. Diagram showing the interconnection of various organizations to control rabies.

It is time to discuss some of the organizations working to eradicate rabies. For instance, the World Health Organization (WHO), the World Organization for Animal Health (OIE), and the Food and Agriculture Organization (FAO) facilitate collaboration between several sectors toward the eradication of rabies. Additionally, they support health strategies, including vaccination campaigns, educational initiatives, and financial assistance for those affected. (41). As a result, these organizations' leadership is crucial, and it is impressive to see how they have cooperated to fight rabies, as shown in figure 7 (12).

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Fig. 7. Elimination of Dog-Mediated Human Rabies Deaths by 2030.

9. One Health Advocacy at the Policy Level

To include elements for the health of humans, animals, and the environment in comprehensive policies, effective campaigning for the One Health approach at the policy level is necessary(4). As shown in Figure 8, effective campaigning for the One Health approach at the policy level is necessary. This strategy has grown in popularity due to its success in addressing complex health issues. The interconnection between human, animal, and environmental health can be highlighted in policy frameworks to allocate resources better and comprehend illness trends.(42). Decision-makers can advocate for comprehensive and long-lasting solutions to public health issues, such as managing zoonotic diseases, including rabies. (43).

Fig. 8. Diagram showing various steps of policy cycle.

Health advocacy must be translated into practical rules and regulations to address global health concerns and avoid zoonotic disease outbreaks adequately.(44). Implementing the One Health policy depicted in Figure 8 requires collaboration between the government, public health organizations, veterinary associations, and environmental departments. (45). These regulations may include cross-sectorial coordination procedures, integrated surveillance and reporting systems, and coordinated disease management plans. (45). By harmonizing legislative frameworks and standardizing procedures, nations can encourage the exchange of crucial information and data. (46). Another part of implementing the One Health policy is using technology and innovation to enhance illness monitoring and response abilities. (47).

To maintain the One Health Plan, adequate finances and resources are required to support research, surveillance systems, and capacity-building operations (48)Stakeholders can encourage the implementation of the One Health Policy by requesting more funding from governments, international organizations, and the business community. (49). Securing funds for cross-sectorial collaborations and collaborative research can lead to innovations in disease prevention, diagnosis, and control techniques. (50). Furthermore, advocating for unique funding sources for the One Health program can ensure ongoing dedication to the cause. (51). By persuading legislators of the benefits of One Health solution for society and the cost-effectiveness of such solutions, advocates can obtain the resources needed to address growing health risks. successfully (52).

For the One Health Plan to succeed, governments, non-governmental organizations, academia, and international organizations must collaborate globally. (53)Collaborative technologies can facilitate the sharing of knowledge, best practices, and insights from successful One Health programs. (54). Stakeholders can access knowledge, pool resources, and collaborate to address global health issues by creating international partnerships. (55). Future disease outbreaks can be promptly contained because early warning systems are supported by international cooperation. (56). Additionally, partnerships with industrial stakeholders and the business sector can promote research on vaccines, surveillance technologies, and disease prevention measures.(57).

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10. One Health in Action: Interdisciplinary Research

Interdisciplinary research is essential when utilizing the One Health concept to address complex health issues such as rabies prevention and control. By bringing together experts from various domains, such as human and veterinary medicine, epidemiology, ecology, and environmental sciences, researchers can obtain complete insights into the dynamics of zoonotic illnesses. (58). Innovative methods have been developed, and transmission channels have been better understood owing to collaborative research projects. (59). This interdisciplinary research enhances our understanding of the relationships between human, animal, and environmental health and makes it easier to create evidence-based preventative measures for zoonotic illnesses, such as rabies, as shown in Figure 9 (60)

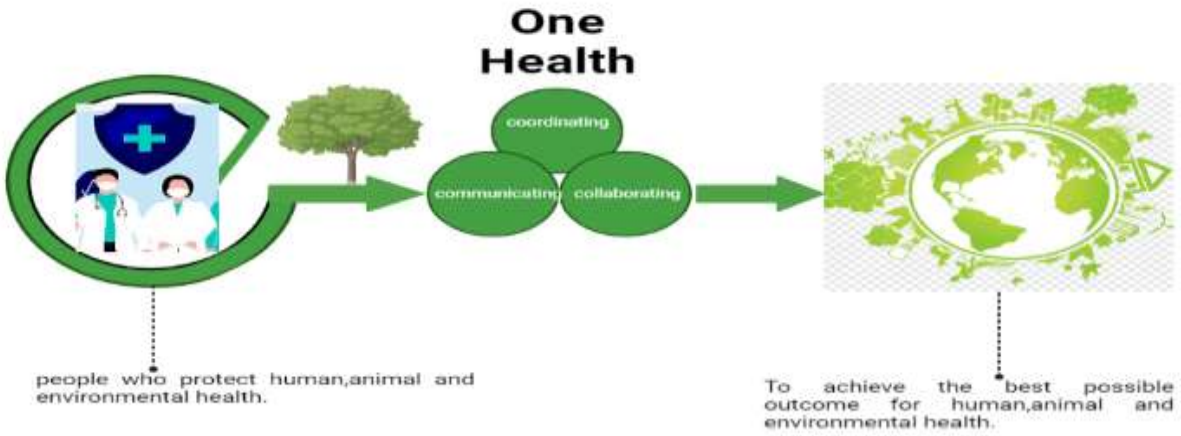

Fig. 9. Diagram showing the role of public health workers along with the One Health Approach to eliminate rabies.

Collaboration across many stakeholders, including public health agencies, veterinary services, wildlife conservationists, and local populations, is essential for effective rabies prevention and control. (61). These organizations can pool their knowledge, resources, and experience through collaborative studies to develop comprehensive methods adapted to specific situations. (62, 63). According to (64), this research may include vaccination efforts for both domestic animals and wildlife and community outreach initiatives to encourage responsible pet ownership and raise knowledge of rabies transmission. Together, these parties can develop sustainable and comprehensive rabies management strategies, easing this devastating illness's burden. (40).

Through technological advancements, practical methods for boosting rabies surveillance and monitoring activities are available. (16). Remote sensing, Geographic Information Systems (GIS), and big data analytics can be used to build maps of high-risk areas and likely disease hotspots. (65). Additionally, real-time reporting platforms and mobile applications can enhance disease surveillance in both human and animal populations, assisting in the early detection of rabies. (66). Developments in molecular diagnostics and viral genomes have also made it possible to quickly and correctly identify rabies strains, assist in epidemic investigations, and identify disease transmission paths. (67). Technology can help public health officials and researchers respond promptly to the risks of fresh rabies. (68).

As seen in Figure 9, encouraging a culture of cooperation and knowledge-sharing is essential to One Health's efforts to prevent the spread of rabies. (69)International conferences, workshops, and online networks allow researchers, practitioners, and policymakers to connect, exchange

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knowledge, and collaborate on joint projects. By creating a shared knowledge base and learning from one another's successes and errors, the international community can improve and sharpen rabies prevention and control strategies over time, bringing us one step closer to a world free of this dreadful illness. (70).

11. Building Resilience: Climate Change and Emerging Diseases

Climate change has become a significant factor affecting rabies transmission dynamics. When global temperatures rise, changes in animal populations, distribution, and behavior are observed. (71). According to (72)These changes impact how reservoir species such as bats interact with susceptible hosts such as domestic animals and people, resulting in altered patterns of disease transmission. Variations in precipitation patterns can also change the distribution of vectors and reservoirs, which can affect animal migration and help rabies spread to new locations. (73)Understanding the intricate interactions between climate change and rabies transmission is essential to creating efficient prevention and control methods in a changing world. (74).

A comprehensive approach is required to effectively manage and avoid the rising hazards posed by new zoonotic diseases such as rabies. The One Health idea is well-equipped to deal with the problems caused by emerging diseases because it acknowledges the deep relationships between human, animal, and environmental health. (75). One Health initiative can improve surveillance, early detection, and fast response capacities to prevent the establishment and spread of rabies by encouraging collaboration among human and animal health professionals, environmentalists, policymakers, and researchers. (76). Implementing integrated risk assessment and mitigation techniques can support coordinated activities, identify possible disease hotspots, and guide preparedness plans. (77).

Sustainable rabies management measures are needed to protect both human and animal populations while protecting the environment in the context of climate change and emerging illnesses. The cornerstone of rabies control initiatives is vaccination campaigns directed at at-risk animal populations such as dogs and wildlife reservoirs. (78). Health authorities can attain high coverage rates and break the transmission cycle by establishing community-based immunization programs. (79). Additionally, encouraging responsible pet ownership can lower the number of stray animals that are possible rabies carriers. (80). This included spaying and neutering pets. Moreover, by avoiding contact between people, domestic animals, and wildlife, integrated environmental management practices, such as efficient waste disposal and habitat conservation, help lower the likelihood of disease spillover. (81). By implementing sustainable measures that align with environmental conservation, we can promote healthier ecosystems, enhance public health outcomes, and increase resilience against the threats posed by climate change and emerging illnesses such as rabies. (82).

12. Engaging the Community: One Health Education and Empowerment

Figure 10 illustrates the importance of public awareness campaigns to manage and prevent rabies

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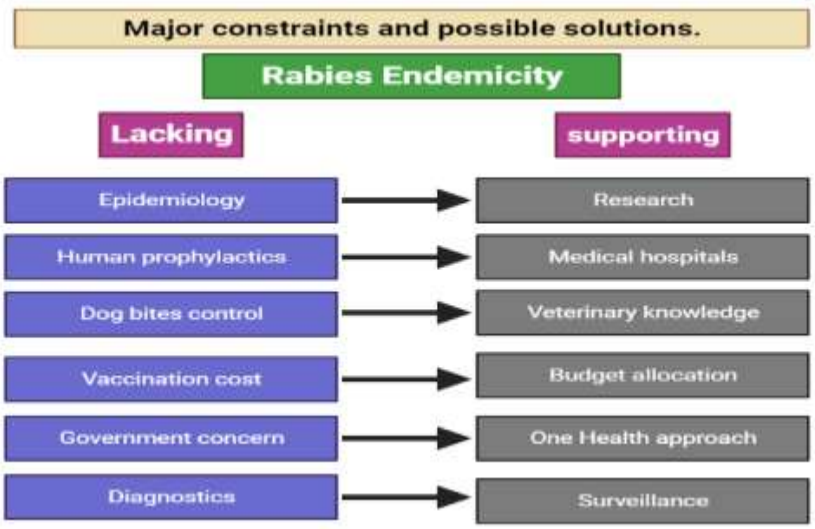

Fig. 10. Diagram showing the major constraints and their best possible solutions.

Suppose communities are to embrace a proactive strategy for disease prevention. In that case, they must be educated on the risks of rabies transmission, the importance of responsible pet ownership, and the benefits of vaccination. (83). Public health campaigns can use various communication tools, such as social media, radio, and community workshops, to provide accurate and understandable information about rabies. (84). Raising awareness about rabies prevention will enable communities to decide whether to report instances that are likely rabies,

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participate in vaccination campaigns, and seek immediate medical assistance in the event of an animal attack. (85).

One Health initiative requires significant community support to be successful. Providing communities with the resources needed to actively participate in zoonotic disease surveillance, prevention, and control operations can increase the success and feasibility of such programs. (86). One health project can address specific community needs and personalize treatments by including local community leaders, healthcare professionals, veterinarians, and environmentalists in the decision-making process. (87). Empowerment can be gained through cooperative projects that encourage ownership and accountability within the community, seminars, training sessions, and projects that create capacity. (88). Participating in the One Health initiative develops a sense of shared responsibility for safeguarding the health of people, animals, and the environment and increasing community resistance to disease outbreaks. (15).

As health advances, it is crucial to cultivate the next generation of advocates and specialists. Educational institutions can effectively promote human, animal, and environmental health interdependence. (13). Future professionals can build a multidisciplinary approach by combining the One Health principle into academic curricula, veterinary and medical training, and environmental research. (89). Through research opportunities and monitoring programs, students might also be encouraged to pursue careers in health-related fields. (90).

13. Conclusion

The idea of One Health has emerged as a potent and essential strategy for solving complicated health issues in the field of zoonotic illnesses, with rabies serving as a notable example. Human, animal, and environmental health interdependence in our connected world is becoming increasingly evident. This brought to light the pressing requirements for cooperation and group efforts. One Health issue allows us to adopt a thorough strategy for illness prevention and control, considering the plethora of factors influencing disease onset and dissemination. By embracing the ideas of One Health, we can create robust healthcare systems that can successfully address the problems posed by rabies and other new illnesses.

The threat of rabies to public health remains entirely accurate, especially in areas with limited resources and poor access to treatment. Each of us, individually and as a community, is responsible for actively participating in rabies prevention efforts. This means giving our pets the rabies vaccine, swiftly notifying the authorities in case of a rabies case, and getting medical help

immediately if an animal bites us. Additionally, pushing for the inclusion of One Health measure at the policy level can spark significant changes in disease surveillance, prevention, and control. By developing and supporting projects that advance the welfare of people, animals, and the environment, we collectively contribute to a safer and healthier world.

Public awareness and education are paramount to empowering individuals to take proactive measures against rabies and other zoonotic diseases. Through public awareness campaigns and educational programs, accurate information regarding disease prevention and the significance of responsible pet ownership must be disseminated. Informed communities are better equipped to shield themselves and their cherished animals when they understand the risks of rabies transmission and the benefits of vaccination. Utilizing various platforms for public awareness campaigns ensures that crucial information reaches diverse populations, including remote areas with high disease burdens.

Ongoing research and innovation are paramount to advance the One Health agenda and effectively combat emerging diseases, such as rabies. Scientific research on disease transmission, monitoring, and control methods is crucial for identifying gaps and crafting evidence-based solutions. Utilizing technology and interdisciplinary research allows us to bolster disease surveillance, provide precise diagnostic tools, and monitor disease outbreaks in real time. Moreover, funding research to comprehend how climate change influences disease transmission helps us proactively address evolving health challenges, reinforce our readiness and response capabilities, and fortify global health systems.

Ultimately, health acts as a bridging force that brings people, communities, and organizations together to pursue health and well-being. We can create a safer, healthier, and more sustainable future for both people and animals if we adopt the One Health tenet. Our shared duties in rabies prevention and health advocacy are based on active engagement, public awareness, and a commitment to research and innovation. Together, we can protect our local economies and the delicate balance between people, animals, and the environment for future generations.

14. Acknowledgements

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15. Conflict of Interest

The authors declare no conflict of interest.

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