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Rabies and Public Health: A Narrative Review on Epidemiology and Control Strategies in Pakistan

A.M. Ali[1], A. Ali[2], M. Bhatti[3]

[1] Department of Public Health, Jinnah Sindh Medical University, Karachi, Pakistan
[2] Department of Public Health, The University of the Punjab, Lahore, Pakistan
[3] Department of Public Health, Bahria University, Karachi, Pakistan

Abstract:

Background:

Rabies remains a major public health concern in regions with large populations of free-roaming dogs and limited veterinary awareness, further complicated by sociocultural barriers to prevention and control. Despite global efforts, the disease continues to cause significant suffering and mortality, underscoring the need for a coordinated, multi-sectoral response. This review synthesizes current evidence on the epidemiology, prevention, and control of rabies in Pakistan, emphasizing the One Health framework, vaccination strategies, and sociocultural challenges, to identify key gaps and propose actionable recommendations toward rabies elimination by 2030.

Methods:

A comprehensive literature search was conducted using PubMed, Google Scholar, and CINAHL to identify studies on rabies published between 2015 and 2024. The review focused on rabies epidemiology, vaccination efforts, control strategies, and key challenges, and used a thematic synthesis approach to identify emerging trends, best practices, and policy recommendations for improving rabies control.

Results:

Results demonstrate the necessity of a One Health approach consisting of mass dog vaccination, management of stray dog populations, improved surveillance, and policy enforcement for rabies eradication. Awareness and education programs that engage the community are pivotal in increasing vaccine uptake and responsible pet ownership. It is also vital to improve and strengthen the laboratory diagnostic capacity to enable early case detection and response. Sabotaging factors such as vaccine shortages, poor surveillance systems, and inadequate implementation of policies are significantly hampering efforts to control rabies on a sustained basis.

Conclusion:

A sustainable rabies elimination strategy must be approached from a multidisciplinary perspective where vaccination coverage, community participation, training, and strong surveillance mechanisms take priority. Global eradication of rabies will only be achieved through strengthening health systems, enforcing animal welfare policies, and integrating public health actions. Future research should also explore the socio-behavioral factors affecting rabies control to improve intervention effectiveness.

Keywords:

Rabies, Pakistan, one Health, Epidemiology, Dog-bite Prevention, Post-exposure Prophylaxis (PEP)

Introduction:

Rabies is an ancient, neglected, and deadly zoonotic disease caused by the *Rabies lyssavirus* of the *Rhabdoviridae* family (1-6). The disease occurs on all continents except Antarctica, with most deaths reported in Asia and Africa (6). India, Pakistan, and Bangladesh are among the top five countries with the highest rabies burden (7). In the South Asian subcontinent, rabies is a major animal-transmitted infection, causing approximately 2,000 to 5,000 deaths annually in Pakistan and about 55,000 globally (8). The virus is almost always fatal if post-exposure treatment is not administered promptly after a bite from a rabid animal. Once inside the body, the virus travels to the central nervous system (CNS), causing severe brain inflammation. Symptoms typically appear within six weeks of exposure and progress from early signs such as malaise, headache, and fever to muscle spasms, agitation, and hydrophobia (2, 6). The infection primarily affects the brain and spinal cord, leading to severe neurological damage. Clinically, rabies presents in two forms: *furious rabies*, characterized by hyperactivity and hallucinations, and *paralytic rabies*, which causes gradual paralysis (4).

Transmission mainly occurs through contact with the saliva of infected animals via bites,

scratches, or licks on broken skin or mucous membranes (3,18). In many cases, people are unaware of the risks and fail to seek timely medical care after exposure (1,9). Rabies remains a significant public health concem globally, particularly in low- and middle-income countries like Pakistan (1,10,14). Most local studies are retrospective and lack detailed data on the circumstances of bites or the type of first aid received (7). The close association between humans and dogs dates back over 12,000 years (11), yet in Pakistan, rising dog-bite cases are largely attributed to a lack of public awareness, uncontrolled stray dog populations, and inadequate vaccine cold-chain management (12). Persistent endemicity in Pakistan is further fueled by weak control programs, financial and political constraints, and limited public education. Proper management involves immediate wound cleaning, antibiotics, and post-exposure prophylaxis (PEP); however, many healthcare providers lack adequate training and awareness to deliver appropriate care (8). Vaccinating at least 70% of the dog population is considered essential for interrupting transmission, and mass vaccination campaigns covering 60–70% of owned dogs have significantly reduced human rabies cases in other regions (13). Unfortunately, the high cost of PEP, poor healthcare infrastructure, and low community awareness continue to impede progress. Rabies remains a low public health priority in Pakistan, and reliable national mortality data are lacking (2). In alignment with global goals, Pakistan aims to eliminate rabies by 2030 through mass dog vaccination, improved access to PEP, and strengthened One Health coordination (9). This review aims to synthesize current evidence on the epidemiology, prevention, and control of rabies in Pakistan, emphasizing the One Health approach, vaccination strategies, and sociocultural challenges, to identify gaps and propose actionable recommendations for achieving rabies elimination by 2030.

Corresponding Author:

Name: Muqadas Bhatt

Affiliation: Department of Public Health, Bahria University.
Email: muqadas.bh@gmail.com

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Methodology:

A comprehensive literature search was conducted using databases such as PubMed, Google Scholar, and CINAHL. Keywords used included "rabies in Pakistan," "rabies epidemiology," "One Health approach," "dog-mediated rabies," "rabies control strategies," and "sociocultural aspects of rabies." Articles published between 2015 –2024 were considered primarily. The search was limited to articles published in English, with a focus on studies conducted in Pakistan and other rabies-endemic countries in South Asia. Relevant studies were screened based on their titles, abstracts, and full texts. Data extraction focused on the epidemiology of rabies, as well as knowledge, attitudes, and practices related to rabies prevention, factors influencing its control, and vaccination strategies. The extracted information was then categorized into major themes, including epidemiology, sociocultural aspects, immunopathology, vaccine development, and control strategies. To synthesize our findings, a narrative approach was employed to integrate and compare results from various studies, highlighting best practices and policy recommendations for rabies elimination in Pakistan.

Epidemiology and disease burden:

Rabies occurs worldwide except in antarctica, with most deaths reported in Asia and Africa, particularly in India, Pakistan, and Bangladesh, which rank among the top five countries with the highest rabies burden (6, 7). Many countries in South Asia, including India, Myanmar, Bangladesh, and Nepal, continue to struggle with rabies control due to the absence of reliable case data, weak surveillance systems, inadequate diagnostic laboratories, and poor public

awareness regarding prevention and post-bite management (8, 15). India reports the highest number of human rabies cases annually (over 20,000), followed by China (3,200 deaths) and Pakistan (2,490 deaths) (16).

Based on disease burden, South Asian countries are categorized as high (Pakistan, India, and Bangladesh), medium (Bhutan, Nepal, and Sri Lanka), and low (Afghanistan) (6). Rabies remains a major yet neglected public health issue in many low- and middle-income countries, including Pakistan. It ranks as the 11th most deadly infectious disease globally, causing around 59,000 deaths each year and an estimated economic loss of 8.6 billion USD in lives, livelihoods, and treatment costs. In Pakistan alone, approximately 50,000 dog-bite incidents and 6,000 deaths occur annually, with rural areas accounting for nearly 84% of fatalities (1). Cases often peak during the summer months, particularly among children.

Despite their political differences, India and Pakistan share a common challenge in combating rabies, a virus transmitted primarily through the saliva of infected animals such as dogs, cats, and bats. Both countries have implemented national control programs focusing on public awareness, dog vaccination, and PEP, yet progress is hindered by inadequate funding, shortage of trained personnel, and poor healthcare access in rural regions (9). In Pakistan, particularly in Karachi, the incidence of dog-bite injuries has risen sharply, leading to high treatment costs and emergency hospitalizations. However, vaccination coverage data remain unavailable, and the continued use of outdated nerve tissue vaccines poses additional challenges (7).

Currently, 25 to 30 new dog-bite cases are reported daily in hospitals across high-risk provinces such as Sindh, Punjab, Khyber Pakhtunkhwa, and Balochistan (7). In Karachi alone, 55–60 dog-bite injuries occur each day. While data on bites from other animals like jackals, foxes, raccoons, and bats are limited, trends show the highest number of dog-bite cases in April (12.5%) and the lowest in May (5.2%). Other months with increased reports include March (11.9%) and February (10.9%), whereas June (7.5%) and July (7%) record fewer incidents (11).

Knowledge, attitude & practice assessment:

Knowledge, attitudes, and practices (kap) regarding rabies play a vital role in its prevention and control. A cross-sectional study conducted in Karachi, Pakistan, from January to June 2022 revealed that individuals aged 31–40 years were at a higher risk of having insufficient knowledge about rabies. Doctors and students also demonstrated moderate gaps in awareness, while residents of Punjab were identified as a high-risk group due to low levels of public awareness. Differences in understanding were also observed among professional groups, doctors and housewives disagreed on the possibility of human-to-human transmission, government employees generally believed it was possible, and teachers remained uncertain (8).

Similarly, a cross-sectional study conducted in Peshawar in February 2022 assessed the KAP of healthcare professionals in tertiary care hospitals to evaluate their awareness and management of rabies. The findings highlighted variations in knowledge and attitudes among healthcare workers: medical officers and nurses showed relatively better understanding, whereas house officers and paramedics exhibited notable knowledge gaps. The study underscored the need for role-specific training and continuous education programs to strengthen rabies prevention, diagnosis, and management practices across healthcare settings (17).

Immunopathology of rabies:

Mechanism of disease caused by the rabies virus:

Rabies is a neurotropic virus, meaning it specifically affects the nervous system. It enters the body through the bite of an infected animal and travels to the CNS, where it triggers severe neurological symptoms and, if left untreated, almost always results in death. The disease's progression involves complex interactions between the virus and the host's immune responses, including alterations to immune and brain functions, as well as disruptions in metabolism and synaptic activity (18, 19).

Rabies virus (RABV) employs various strategies to avoid detection and attack by the host immune system. It weakens the host’s immune response by inhibiting gene expression, masking pathogen-associated molecular patterns, and altering cytokine signaling pathways. These immune evasion tactics are vital for the virus to

establish an infection and cause the disease (19). Astrocytes, which are glial cells in the CNS, play an essential role in limiting the replication of the rabies virus. When exposed to lab-attenuated RABV, these cells activate the innate immune response, prompting the production of interferons and inflammatory cytokines that help control the infection. In contrast, wild-type RABV is able to bypass this immune response, enabling it to persist within the CNS (20).

Advancements in rabies vaccine development and management:

Although intradermal vaccination is cost-effective and resource-saving, access to rabies immunoglobulin (RIG) is still very limited due to the high cost and logistical difficulties. Countries such as Bangladesh and Sri Lanka have made significant progress in providing either free or low-cost PEP at public health facilities, and the key to reaching elimination goals appears to be political commitment and a strong health system (21).

Cell-culture vaccines:

The cell culture system has now been made visible in the modern era for mass producing rabies vaccines. Their vaccination schedules involve the use of stabilized cell lines like hamster kidney cells as well as African green monkey kidney cells (Vero cells). This allowed increased safety and higher scalability in production. The purified Vero cell rabies vaccine (PVRV) was quickly embraced and endorsed by the World Health Organization (WHO). Treatment of rapidly effective rabies management will include remedial structural weaknesses within the healthcare systems. The introduction of the very thrifty intradermal four-dose regimen as opposed to the classical five-dose intramuscular one is expected to bring a substantial reduction in overall treatment costs (22).

MRNA and new-generation vaccines:

MRNA vaccines, such as cv7201, have shown promising results in pre-clinical studies by inducing neutralizing immune responses in animals. However, phase 1 human trials showed that while mRNA vaccination is safe, the immune response varies with the administration method used, and further development is needed for prophylactic use (23). Improvements have been made in mRNA vaccines that led to better structural modifications and delivery systems, making them a promising alternative to traditional vaccines. Their ability to be produced quickly and cost-effectively further enhances their potential.

Dog population management and rabies control strategies:

Stray dogs without owner control are the main ones for rabies transmission. The number of stray dogs is estimated to be about 3 million in Pakistan, and this leads to more than 1 million cases being reported every year due to dog bites. Effective dog population management (DPM) is the most important for rabies transmission control. Strategies like sterilization, the establishment of shelters, and vaccination campaigns are recommended. Such actions not only assist in the population control of stray dogs but also help in the improvement of health management systems, making it much safer for humans as well as pets (25).

Post-exposure prophylaxis:

Rabies control depends largely on the prompt administration of PEP, which remains the most effective method of preventing infection after exposure. The intradermal (ID) vaccination route is particularly advantageous due to its dose-sparing benefits, cost-effectiveness, and practicality for healthcare workers. However, access to PEP in many rabies-endemic countries, including Tanzania, continues to be limited by high costs, supply chain inefficiencies, misinformation, and vaccine shortages. These barriers often result in many exposed individuals failing to seek medical care or complete the full PEP course (26).

In Tanzania, research indicates that the incidence of bite injuries is closely linked to the size of the dog population, highlighting the importance of integrating the One Health approach to address both human health and animal population control. The introduction of free and decentralized PEP services has proven effective in improving access to treatment and reducing delays in initiation. Additionally, mobile phone–based surveillance and contact tracing have

demonstrated that decentralized systems equipped with adequate cold-chain capacity can successfully support timely PEP delivery (26).

One health approach:

The One Health approach is a collaborative strategy that brings together multiple sectors and disciplines to improve health outcomes. It recognizes the fact that people, animals, plants, and their shared environment are all interconnected, and a change in one compartment can significantly affect the others. This approach is especially important for controlling and preventing zoonotic diseases like rabies, which continues to be a major public health issue in many regions. The WHO has set a goal directed towards everybody globally that by year 2030 there should be no human who dies from rabies due to dogs, stressing the need for cross-sector collaboration with a "One Health" approach. Vaccinating dogs is the bedrock of rabies control strategies because it reduces transmission to humans (21).

Especially with One Health approaches to treatment for human, animal, and environmental health, it has been increasing importance unto rabies control (16). They lack RIG and modern vaccines, rendering their care full of gaps, with many being sent to private hospitals, where treatment becomes prohibitive to many. This is the way that opens into cheaper options like the TRC-id regimen, alignment with proper training to healthcare workers, which has the potential to dramatically improve rabies management, treatment costs, and ultimately even lower rabies incidence changes in deaths where healthcare access is very limited (27).

Implementation of one health in rabies control:

1. **Integrated bite case management (IBCM):**

IBCM comprises a major proponent in the One Health for working outside the health and veterinary sectors, and is set to improve collaboration and rabies detection and control. For instance, in Tanzania, when IBCM was introduced, this resulted in an increase in the identification of rabid animals, which is fundamentally a step toward addressing disease dissemination. There was also improved communication between the health and veterinary sectors thus leading to a more efficient response to rabies management. However, the implementation was also characterized by some of the following challenges, namely a lack of conducive training environment for the staff involved, and limited funding to ensure program sustainability (28).

2. **Mass dog vaccination:**

Mass dog vaccination is a key component of the One Health framework and an essential strategy for interrupting rabies transmission between animals and humans. Achieving at least 70% vaccination coverage in dog populations establishes herd immunity, significantly reducing human exposure. Successful programs in countries like Chad and Tanzania have demonstrated notable declines in both canine and human rabies cases, highlighting the approach's effectiveness and cost-efficiency (20). Sustained success, however, depends on political commitment, adequate funding, and reliable vaccine distribution systems.

3. **Public awareness and education:**

Campaign ads are necessary to educate the communities on what they should do to avoid rabies and how to care for wounds, use disinfectants, and give rabies vaccinations to pets and people. These measures can lead to a profound drop in the number of rabies cases and higher health standards in the community (25).

Low community awareness is amongst the problems faced in rabies control, as a result of which victims seek medical help late after being bitten by dogs. Hardly do a number of victims know that a bite is not very serious on the contrary; it may need their immediate PEP, which in turn leads to fatality risk. For example, the old transport of nerve tissue vaccine in Pakistan has fueled vaccine hesitancy in the country, which has certainly made rabies control efforts ineffective (29).

According to WHO recommendations, effective rabies management requires mass dog vaccination and neutering to establish herd immunity. Success stories from countries in Southeast Asia have illustrated that with public participation and building strong health systems, enormous reductions in rabies have been made possible. Thus, adopting a One Health model- that is synergetic by way of inter-sectoral collaboration with sharing of data and

community engagement is essential in achieving the objective of a rabies-free Pakistan by 2030 (29).

Challenges and comparative analysis of rabies control strategies:

Various hindrances, including substandard surveillance systems, socio-economic disparities, and the high cost of vaccines and PEP, continue to undermine rabies control efforts by limiting public awareness and access to treatment. Insufficient funding and poor infrastructure have hindered the establishment of sustainable surveillance mechanisms across much of Africa and Asia, directly affecting the early detection and management of rabies cases. While strategies such as mass dog vaccination have proven highly effective in breaking the transmission cycle and reducing human cases, their success is often constrained by weak logistics, inadequate cold-chain systems, and inconsistent coverage. The One Health approach enhances coordination between human and animal health sectors but faces implementation challenges due to limited collaboration, funding gaps, and policy weaknesses. Similarly, PEP remains the most reliable preventive measure after exposure, yet its effectiveness is hampered by high costs, supply shortages, and delays in administration. Moreover, in many countries, rabies control is not integrated into national health programs, and existing initiatives often lack proper monitoring and evaluation frameworks (24).

Sociocultural and behavioral aspects of rabies:

Sociocultural and behavioral factors play a crucial role in shaping the prevention and management of rabies, especially in resource-limited settings where access to healthcare and education is often inadequate. Misconceptions about the disease, such as beliefs that rabies can be cured through traditional remedies or that dog bites are harmless, contribute to delays in seeking medical attention. In many rural communities, people often turn to traditional healers instead of formal healthcare facilities, leading to missed opportunities for timely PEP. Cultural attitudes toward dogs also affect control measures, as in some areas dogs are viewed as protectors or part of local traditions, making mass vaccination or culling programs socially sensitive. Therefore, there is an urgent need for community-based education programs that promote accurate knowledge about rabies transmission, symptoms, and treatment. Collaborative, multi-sectoral approaches that integrate health authorities, veterinary services, and local leaders are essential to overcoming behavioral barriers and enhancing rabies prevention and control at both community and global levels.

Healthcare-seeking behavior:

Decisions about seeking healthcare after an animal bite are often influenced by accessibility, financial constraints, and cultural beliefs. In many communities, culling—a common response during rabies outbreaks—faces resistance due to cultural or religious values surrounding dogs. For instance, in Bali, where Hindu beliefs regard dogs as protectors and companions, culling is seen as inhumane and is often opposed. However, in some areas, fear of rabies outbreaks has temporarily shifted public attitudes, leading people to reluctantly accept culling as a necessary control measure, even though it remains controversial and culturally sensitive (30).

The cost of rabies vaccines for both humans and animals presents another major barrier in LMICs, In Cameroon, for example, dog owners are required to contribute financially to national vaccination campaigns, limiting participation and resulting in low vaccination coverage, particularly among poorer households. This economic burden disproportionately affects marginalized families who are least able to afford preventive care. Additionally, traditional healing practices remain widely used, especially among older adults and men, due to cultural beliefs, limited access to healthcare facilities, and the high perceived cost of biomedical treatment. Therefore, overcoming these barriers requires affordable vaccination programs and culturally sensitive education to promote timely medical care and improve rabies prevention within communities (30).

Recommendations:

Considering the One Health strategy for combating rabies in Pakistan, priority should be given to mass dog vaccination, affordable treatment options, and community awareness initiatives. Vaccination programs targeting both owned and stray dog populations—supported by spaying, neutering, and shelter management—can significantly reduce transmission risks. Public education on rabies prevention, wound care, and timely post-exposure treatment is essential to improve early response and reduce mortality. Strengthening research capacity, laboratory diagnostics, and surveillance systems will enhance case detection and monitoring. Furthermore, sustainable progress requires strong national policies, adequate financing, and international collaboration with organizations such as the WHO to ensure long-term rabies control and eventual elimination.

Conclusion:

Rabies continues to pose a significant threat to public health, being mainly a disease acquired by human-dog interactions and free-roaming dog populations. Effective rabies control encompasses several options, including mass dog vaccination, population control through spaying and castrating dogs, and mass information campaigns. Strengthening surveillance systems and diagnostic capacities and enforcing policies with sufficient resources are critical to maintaining momentum. Collaboration between government agencies, healthcare providers, and international bodies will further provide support for adequate rabies control initiatives. Overall, an aggressive, interdisciplinary approach is essential to reduce rabies transmission, improve public health outcomes, and ultimately achieve rabies elimination.

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Ethical Declarations

This review was conducted following ethical guidelines for systematic literature research. All data was obtained from publicly available sources, and no human or animal subjects were involved.

References:

1. Ahmed T, Hussain S, Zia UU, Rinchen S, Yasir A, Ahmed S, Khan WA, Tahir MF, Ricketson R. Knowledge, attitude and practice (KAP) survey of canine rabies in Khyber Pakhtunkhwa and Punjab Province of Pakistan. BMC public health. 2020 Dec;20:1-2.
2. Salahuddin N, Gohar MA, Jamali S, Qureshi MA, Baig-Ansari N. Analysis of human rabies deaths reported at two hospitals in Karachi, Pakistan: a call to save lives by reforming rabies prevention facilities. Transactions of The Royal Society of Tropical Medicine and Hygiene. 2023 Jul;117(7):479-84.
3. Shan H, Maqbool S, Zulfiqar R, Shan M, Baber M, Jaffry TN. Assessing rabies knowledge and practice from a one health lens in healthcare professionals in Sargodha district, Pakistan: A zero by 2030 approach. Journal of University Medical & Dental College. 2023 Feb 14;14(1):549-55.
4. Habib A, Principe UE, Ashraf Z, Imran M. Epidemiology of Rabies and the Control Challenges. Biotica Research Today. 2020;2(11):1201-4.
5. Ahmad W, Naeem MA, Akram Q, Ahmad S, Younus M. Exploring rabies endemicity in Pakistan: Major constraints & possible solutions. Acta tropica. 2021 Sep 1;221:106011.
6. Khan A, Ayaz R, Mehtab A, Naz K, Haider W, Gondal MA, Umer M, Afzal MI, Shah NA, Afzal MS, Yayi G. Knowledge, attitude & practices (KAPs) regarding rabies endemicity among the community members, Pakistan. Acta tropica. 2019 Dec 1;200:105156.
7. Khan UR, Soomar SM, Ghazi SM, Naeem R, Kerai S, Jamali S. Epidemiological pattern and management of dog bite injuries in Karachi, Pakistan: A cross-sectional study. Injury. 2023 Aug 1;54:110473.
8. Shaikh SU, Zaidi F, Shaikh Z, Fahim MF. Rabies: Perils and Prevention, an Insight into Practices and Perception in Residents of Pakistan. Iranian biomedical journal. 2022 Dec 19;27(1):66.
9. Kumar H, Sharma V, Kumar B. Divided by borders, united by rabies: A call for integrated rabies control in India and Pakistan. New Microbes and New Infections. 2023 Nov 4;55:101191.

10. Kumar H, Bakhru D. Rabies in Pakistan: A never ending challenge. Annals of medicine and surgery. 2022 Oct 1;82.
11. Ali MI, Jamali S, Ashraf T, Ahmed N. Patterns and Outcomes of dog bite injuries presenting to emergency department in a tertiary care hospital at Karachi. Pakistan Journal of Medical Sciences. 2021 May;37(3):794.
12. Afzal S, Nasir M, Bhaya MN, Junaid K, Arshad A, Raza MZ, Ali MA, Ahmad W, Yasobant S. Multifactorial Complexity and Zoonotic Aspects of Dog-Mediated Human Rabies in Pakistan. Pakistan Veterinary Journal. 2022 Oct 1;42(4).
13. Davlin SL, VonVille HM. Canine rabies vaccination and domestic dog population characteristics in the developing world: a systematic review. Vaccine. 2012 May 21;30(24):3492-502.
14. Ahmad W, Naeem MA, Akram Q, Ahmad S, Younus M. Exploring rabies endemicity in Pakistan: Major constraints & possible solutions. Acta tropica. 2021 Sep 1;221:106011.
15. Ahmad T, Haroon, Khan M, Murad MA, Baig M, Murtaza BN, Khan MM, Harapan H, Hui J. Research trends in rabies vaccine in the last three decades: a bibliometric analysis of global perspective. Human Vaccines & İmmunotherapeutics. 2021 Sep 2; 17(9):3169-77.
16. Shah SI, Beg MA, Nadeem MS, Fiaz M, Kayani AR, Rashid N, Irfan M. Occurrence of rabies and dog bite in Rawalpindi district, Pakistan. Annals of PIMS ISSN. 2016;1815:2287.
17. Ahmad A, Inayat F, Ullah N, Rasul S, Bakhtiar S, Shad Z, Ahmad Z. Knowledge, attitudes, and practices of healthcare professionals regarding rabies in tertiary care hospitals: A cross-sectional study in Peshawar, Pakistan. PLOS Neglected Tropical Diseases. 2024 Jun 10;18(6):e0012238.
18. Bastos V, Pacheco V, Rodrigues ÉD, Moraes CN, Nóbile AL, Fonseca DL, Souza KB, do Vale FY, Filgueiras IS, Schimke LF, Giil LM. Neuroimmunology of rabies: New insights into an ancient disease. Journal of Medical Virology. 2023 Oct;95(10):e29042.
19. Singh R, Singh KP, Cherian S, Saminathan M, Kapoor S, Manjunatha Reddy GB, Panda S, Dhama K. Rabies–epidemiology, pathogenesis, public health concerns and advances in diagnosis and control: a comprehensive review. Veterinary Quarterly. 2017 Jan 1;37(1):212-51.
20. Tian B, Zhou M, Yang Y, Yu L, Luo Z, Tian D, Wang K, Cui M, Chen H, Fu ZF, Zhao L. Lab-attenuated rabies virus causes abortive infection and induces cytokine expression in astrocytes by activating mitochondrial antiviral-signaling protein signaling pathway. Frontiers in immunology. 2018 Jan 19;8:2011.
21. Li AJ, Sreenivasan N, Siddiqi UR, Tahmina S, Penjor K, Sovann L, Gunesekera A, Blanton JD, Knopf L, Hyde TB. Descriptive assessment of rabies post-exposure prophylaxis procurement, distribution, monitoring, and reporting in four Asian countries: Bangladesh, Bhutan, Cambodia, and Sri Lanka, 2017–2018. Vaccine. 2019 Oct 3;37:A14-9.
22. Jabbar A, Ahmadi A, Irm N, Naseeb I, Madadi S, Lucero-Prisno III DE. Rabies in Pakistan: Policies and recommendations. Public Health Challenges. 2024 Mar;3(1):e168.
23. Alberer M, Gnad-Vogt U, Hong HS, Mehr KT, Backert L, Finak G, Gottardo R, Bica MA, Garofano A, Koch SD, Fotin-Mleczek M. Safety and immunogenicity of a mRNA rabies vaccine in healthy adults: an open-label, non-randomised, prospective, first-in-human phase 1 clinical trial. The Lancet. 2017 Sep 23;390(10101):1511-20.
24. Hassnain M, Ahmad W, Akram Q, Khan MA, Ali MA. Quadripartite Vision and Mission of Dog-Mediated Rabies Elimination: Cross Border Transmission Threats: Cross border transmission of dog-mediated rabies and the Quadripartite vision of 0 by 30. Proceedings of the Pakistan Academy of Sciences: B. Life and Environmental Sciences. 2024 Apr 29;61(S).
25. Nazar, M., Rehman, F., Asif, H., Hashmi, H., Rehman, A., Arshad, M., Hussain, K., Shahzad, M., Ullah, Z., & Awais, M. Progressive Control and Management Strategies in the Elimination of rabies among the stray dog (Canis familiaris)

Population in Pakistan. Biological and Clinical Sciences Research Journal. 2024 5; i1.819.
26. Changalucha J, Steenson R, Grieve E, Cleaveland S, Lembo T, Lushasi K, Mchau G, Mtema Z, Sambo M, Nanai A, Govella NJ. The need to improve access to rabies post-exposure vaccines: lessons from Tanzania. Vaccine. 2019 Oct 3;37:A45-53.
27. Salahuddin N, Gohar MA, Baig-Ansari N. Reducing cost of rabies post exposure prophylaxis: experience of a tertiary care hospital in Pakistan. PLOS Neglected Tropical Diseases. 2016 Feb 26;10(2):e0004448.
28. Lushasi K, Steenson R, Bernard J, Changalucha JJ, Govella NJ, Haydon DT, Hoffu H, Lankester F, Magoti F, Mpolya EA, Mtema Z. One health in practice: using integrated bite case management to increase detection of rabid animals in Tanzania. Frontiers in public health. 2020 Feb 14;8:13.
29. Mubashir A, Hussain SA. Is Pakistan doing enough to eradicate rabies by 2030? Journal of the College of Physicians and Surgeons Pakistan. 2021 May 1;31(5):614-5.
30. Widyastuti MD, Bardosh KL, Sunandar ,Basri C, Basuno E, Jatikusumah A, Arief RA, Putra AA, Rukmantara A, Estoepangestie AT, Willyanto I. On dogs, people, and a rabies epidemic: results from a sociocultural study in Bali, Indonesia. Infectious diseases of poverty. 2015 Dec;4:1-8.

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