Rabies: Pathogenesis, Prevention and Control Strategies Under the One Health Framework

Anxin Miao *

KangChiao International School, Jiangsu, China

* Corresponding Author Email: anniemiao11@gmail.com

Abstract. Rabies is an acute zoonotic infectious disease caused by the rabies virus (RABV) and remains a significant challenge in global public health. Although China has significantly reduced the incidence rate in recent years through measures such as canine immunization, post-exposure prophylaxis, and health education, problems such as insufficient canine immunization coverage, difficulties in managing stray animals, and weak public awareness of prevention still exist in some areas, making the rabies control situation still severe. This article systematically reviews the biological characteristics, transmission routes, and pathogenic mechanisms of the RABV based on relevant research, and focuses on summarizing key prevention and control strategies such as animal immunization, pre-exposure prophylaxis, standardized post-exposure prophylaxis, and health education. Studies suggest that dogs and cats remain the main sources of infection for humans. Continuing to promote animal immunization, standardized post-exposure prophylaxis, strengthened stray animal management, and public health education are key measures to reduce the risk of rabies transmission and decrease human cases. Existing research mainly focuses on summarizing prevention and control measures, with relatively insufficient comparative analysis of the effectiveness of prevention and control in different regions and long-term implementation strategies. Future efforts should further strengthen the construction of a zoonotic prevention and control system under the "One Health" concept, improve vaccine coverage and primary healthcare service capabilities, and improve cross-departmental collaborative prevention and control mechanisms.

Keywords: Rabies; public health; animal disease.

1. Introduction

Rabies is a very dangerous and serious disease. It is one of the most dangerous diseases in the world. If a person is infected with rabies, they have a 100% chance of dying. This makes it a threat that is very serious to people's health around the world. Every year, tens of people in one thousand people die from rabies around the world. Most of these deaths happen because of dog bites. In fact, 99% of rabies cases come from pets such as dogs. Many of the patients are children under 15 years old. And most cases are in some poor countries in Asia and Africa, where people cannot easily get the cure when they get bitten and need it [1].

China once had problems with this dangerous disease for a long period. In 2007, the number of rabies cases was very high. After that, the number decreased for 16 years because more dogs got vaccinated once they were born. In addition, more people learned that rabies are a disease that has a high mortality rate, and people are able to get treatment after being bitten accidentally. But recently, the number of cases has started to go up again. In 2025, there were 244 reported cases, and 233 of them unfortunately died. More than 95% of people who got infected with rabies died. This shows that rabies is still a big and serious problem in China.

Rabies is a serious and dangerous disease. It can attack human's nervous systems. When animals with this virus bite humans, the rabies virus (RABV) travels along the nerves to the brain. It can take weeks or even months for them to arrive in human's brains. During this time, if a person gets treatment, they won't have any problems and will be safe. But once the virus gets to the brain, the person starts to show symptoms. That is why rabies are so dangerous, because there are no methods to cure once the virus enters the brain.

The World Health Organization (WHO) wants to control the high mortality situation caused by rabies by 2030. There are three important things that can help people to achieve this goal. First of all,

try to get all dogs and other animals vaccinated. Secondly, make sure people can get treatment as fast as possible if they are bitten. Thirdly, promoting and educating people about the seriousness and dangers of rabies, let them recognize getting bitten by animals is not an easy case.

Around the world, there are still many problems that make it hard to control rabies. Not enough dogs get vaccines, especially in villages and faraway places. Also, some animals are hard to get vaccinated because it is hard to control some. And some people do not know what to do when they are bitten by a dog. They may not know what to do after getting bitten or even just ignore the wound. There are also some ideas are wrongly believed by a lot of people. Such as angry and aggressive dogs can spread RABV, and docile dogs will not even if they bite them,

This essay will introduce about how RABV works and how it spreads. This paper also introduces methods to prevent rabies from spreading, like giving vaccines to dogs, helping people who get bitten, and teaching communities about rabies. By looking at what works and what does not work in China, this essay hopes to find better ways to fight rabies and help the world reach the goal of ending rabies by 2030.

2. Biological Characteristics

2.1. Structure and Gene Characteristics

RABV is an enveloped, bullet shaped, about ~180 × 75 nm, with an inner filamentous core and surrounding membranes bearing surface spikes [2]. Its structure and genes are strictly linked to how it is organized, infects cells, and causes disease. Compared to other common viruses, the RABV is not highly resistant in the external environment. It can be killed by common disinfectants such as sunlight and high temperature. However, once it enters the body of warm-blooded animals, it will show strong infectivity and pathogenicity [3].

2.2. Host Range

The RABV has an extremely wide host range and can infect almost all types of mammals. In natural environments, long-term and stable virus transmission mainly occurs in bat populations and medium-sized carnivores. In contrast, most other mammals are only accidental or spillover hosts. They may be infected after exposure but cannot independently live with long-term virus transmission. The host adaptability of the RABV is affected by many factors, including host physiological characteristics, genetic relationships between species, and regional geographical environments. These conditions determine the distribution of rabies hosts and the possibility of cross-species infection in different regions.

2.3. Pathogenic Mechanism

All warm-blooded mammals are potential hosts for RABV, but domestic dogs and cats are the most common infection sources closely related to human life. Wild animals such as bats, foxes and wolves also carry the virus and cause sporadic infection cases. The infection process is similar in different host animals. After an animal is infected, the virus gradually replicates in local tissues and finally accumulates in the salivary glands. When infected animals bite or scratch humans, the virus enters the human body through saliva and broken skin. The most dangerous feature of the virus is its strong neurotropism. It specifically invades and destroys human nerve cells, gradually causing severe encephalitis [4]. After clinical symptoms appear, patients will show typical signs such as hydrophobia, photophobia, wind fear, mental disorder and muscle spasms. At this final stage, the disease is almost incurable and leads to a 100% fatality rate.

3. Transmission Mechanism

3.1. Main Transmission Routes

Human rabies infections almost always come from direct contact with infected animals, and animal bites or scratches are the most common transmission route by far. Statistics show over 99% of human rabies cases originate from dog bites. When an infected dog's saliva touches fresh broken skin, tiny virus particles can enter human tissue smoothly and start the incubation process. Even shallow scratches that barely bleed carry infection risks, as invisible skin cracks can let the virus pass through easily. Besides bite wounds, mucous membrane contact is another valid transmission way. If people's eyes, mouth or nasal lining touch saliva from infected animals, the virus can invade the body without obvious skin injuries. A small number of rare special infection cases have been recorded, such as people handling infected animal carcasses without protective gloves or slaughtering sick wild animals. Though these incidents happen rarely, they still carry hidden infection risks that cannot be ignored in public health control.

3.2. Influencing Factors of Virus Transmission

A set of different factors work together to decide whether virus exposure will turn into real rabies infection. First, wound conditions play a decisive role. Deep, multiple wounds, or injuries on the head and face bring much higher risks, since these areas are close to the brain and shorten the time, the virus needs to reach central nerve tissue. Second, the infected animal's disease stage changes infectivity greatly. Animals that have started showing rabies symptoms hold great virus loads in their saliva, so their bites are far more dangerous than bites from animals still in the silent incubation stage. Thirdly, human first-aid behavior directly affects infection chances. People who skip thorough scar washing, use the wrong cleaner, or delay hospital visits for vaccine shots face a sharp rise in infection risk [5]. Apart from individual exposure conditions, environmental factors also matter, such as rural areas with dense stray animal populations, and less pet management rules have far more frequent rabies exposure incidents every year [6].

3.3. Virus Circulation and Human Infection Risk

In most residential areas around the world, domestic dogs and unmanaged stray dogs maintain the long-term natural circulation of RABV. In villages, suburban zones and small towns without strict animal control, stray dogs without vaccine protection form a lasting virus reservoir [7]. These dogs fight and bite each other, spreading the virus within animal groups and keeping the infection cycle active all year long. Unlike many contagious diseases, daily human-to-human rabies transmission does not exist. Only extremely rare medical cases, such as organ transplants from undiagnosed infected patients, may lead to human cross-infection [8]. This key feature proves all human rabies cases trace back to animal sources. Cutting off viral circulation among animal groups is the core method to lower human infection risks fundamentally [9]. Without systematic animal vaccination and stray animal management, hidden viral reservoirs will always remain, and rabies exposure accidents will keep happening repeatedly.

4. Prevention and Control Measures

4.1. Animal Prevention and Control

Animal prevention is the most fundamental way to control rabies, because almost all human rabies cases originate from infected animals. Among all infection sources, dogs are the main carrier and spreader of the RABV [10]. Therefore, regular vaccination for domestic dogs and cats is the core measure to block virus transmission. Governments and communities should carry out regular pet vaccination activities to improve overall vaccine coverage [11]. At the same time, stray animal management is also very important. A large number of unvaccinated stray dogs live in cities and rural

areas, forming a stable virus reservoir. Relevant departments need to strengthen stray animal monitoring, properly resettle stray groups, and reduce animal fighting and biting behavior. Effective animal control can greatly reduce the probability of human exposure and fundamentally lower the rabies epidemic risk.

4.2. Prevention Before Human Exposure

Pre-exposure prevention means vaccinating high-risk groups before they are exposed to RABV. This is mainly aimed at people who often contact animals, such as vets, animal breeders, pet shop workers and laboratory staff. These groups of people face long-term and frequent exposure risks, so pre-vaccination can help their bodies produce antibodies in advance. Once accidental exposure occurs, the risk of infection can be greatly reduced. Pre-exposure vaccination follows a simple and safe immune procedure. It provides stable long-term protection and is an essential preventive method for professional high-risk personnel.

4.3. Public Health and Community Prevention and Control

Standard post-exposure treatment is the most effective emergency measure to avoid rabies after animal exposure. Timely and correct wound disposal and standardized vaccination can almost completely prevent rabies infection. After being bitten or scratched, the scar should be dealt with as fast as possible, such as continuously washing with soap and running water for more than 15 minutes to flush out residual virus, followed by timely disinfection [12]. After first aid, exposed individuals must complete the full course of rabies vaccine according to medical standards. For deep wounds, head and face injuries or severe exposure conditions, rabies immunoglobulin is required to enhance local immune protection [13]. Any delay, interruption, or inefficient treatment will allow the virus to invade the central nervous system, resulting in serious and fatal consequences [14].

5. Research and Application Progress

5.1. Existing Vaccine types and immunegenicity

Currently, cell culture rabies vaccines are the most widely used vaccines in the world. Compared with traditional vaccines, they have higher safety, fewer side effects and better immune effects. Existing vaccines are divided into animal vaccines and human vaccines. Animal vaccines are mainly used for dogs and cats to cut off the virus source. Human vaccines include pre-exposure vaccines for high-risk groups and post-exposure vaccines for exposed people [15]. When vaccinated strictly in accordance with the procedure, the vaccine can stimulate the human body to produce enough antibodies to resist RABV and achieve a high protection rate.

5.2. Common Issues and Responses to Vaccination

With the development of medical technology, scientists are constantly developing rabies vaccines. Traditional vaccines require multiple injections, which brings inconvenience to people in rural areas. Now, researchers are developing long-acting single-dose vaccines to simplify the vaccination process [16]. In addition, new vaccine adjuvants and new delivery systems are being studied to make vaccines have a faster and last longer effection. Some teams are also developing oral vaccines for wild animals, which can reduce the virus circulation among wild animal groups more conveniently [17]. These new research directions greatly help improve the efficiency of global rabies prevention.

5.3. Common Questions and Answers About Vaccination

Although rabies vaccines are highly effective, there are still some practical problems in actual use. Irregular vaccination, delayed injection and insufficient vaccine coverage may cause immune failure. Moreover, a small number of people will have some physical reactions after vaccination, such as redness on the body and mild fatigue, but these symptoms will disappear quickly and are safe overall

[18]. At present, rabies vaccines produced in regular institutions have stable quality and high safety. Standardizing vaccination management and improving public compliance with vaccine procedures can further maximize the protective effect of vaccines [19].

6. Conclusion

This paper sorts out the biological features of the RABV and corresponding prevention and control strategies based on existing research data. The bullet-shaped virus has weak survival ability outside hosts, yet its strong neurotropism makes it extremely deadly once it invades human nerve tissue. Dogs and cats are the main infection sources for humans, while bats and wild carnivores keep the virus circulating in nature. After entering human bodies through bites, the virus will trigger fatal encephalitis once clinical symptoms appear, with nearly no chance of survival.

To cut off rabies transmission, multi-layered prevention work is essential. Mass vaccination and management of stray animals serve as the basic barrier to reduce virus carriers. Pre-exposure shots protect workers with frequent animal contact, and standardized post-bite wound care plus vaccines can save most exposed people. Though these methods are mature, uneven pet vaccine coverage and incomplete public first-aid knowledge still lead to recurring infection cases in China.

In general, rabies is fully preventable with coordinated efforts from governments, communities and individuals. Sustained animal immunization, standardized medical services and long-term popular science education will steadily lower infection risks. With consistent implementation of all control measures, the global target of eliminating dog-transmitted human rabies by 2030 can be realized step by step.

References

[1] Khairullah A, et al. Tracking Lethal Threat: In-Depth Review of Rabies. Open Veterinary Journal, 2023, 13: 1385-1399. doi:10.5455/ovj. 2023.v13.i11.1.

[2] Zhang Y, et al. Proteomic Profiling of Purified Rabies Virus Particles. Virologica Sinica, 2019, 35: 143-155. doi:10.1007/s12250-019-00157-6.

[3] Guichard P, et al. Three-Dimensional Morphology of Rabies Virus Studied by Cryo-Electron Tomography. Journal of Structural Biology, 2011, 176(1): 32-40. doi: 10.1016/j.jsb.2011.07.003.

[4] Feige L, et al. Susceptibilities of CNS Cells Towards Rabies Virus Infection Is Linked to Cellular Innate Immune Responses. Viruses, 2022, 15: 88. doi:10.3390/v15010088.

[5] Warrell DA. Clinical Manifestations and Pathogenesis of Human Rabies Encephalitis. Infectious Disease Clinics of North America, 2019, 33(4): 809-833. doi: 10.1016/j.idc.2019.08.003.

[6] Rupprecht CE, Hanlon CA, Hemachudha T. Rabies Pathogenesis and Clinical Disease. Infectious Disease Clinics of North America, 2018, 32(3): 607-624. doi: 10.1016/j.idc.2018.04.004.

[7] World Health Organization. Rabies Fact Sheet. World Health Organization, 2024. Available from: https://www.who.int/news-room/fact-sheets/detail/rabies.

[8] Centers for Disease Control and Prevention. Rabies Exposure and Transmission Guidelines. NCBI Bookshelf, 2025. NBK448076. Available from: https://www.ncbi.nlm.nih.gov/books/NBK448076/.

[9] Rupprecht CE, et al. Global Circulation of Canine Rabies Virus and Elimination Pathways. PLOS Neglected Tropical Diseases, 2020, 14(5): e0008210. doi: 10.1371/journal.pntd.0008210.

[10] FAO, OIE, WHO. Oral Vaccination of Dogs Against Rabies: Recommendations for Field Application and Integration into Dog Rabies Control Programmes. WHO Press, 2023. doi:10.4060/cb4896en.

[11] Hampson K, et al. The Transmission Dynamics of Rabies in Dog Populations. Proceedings of the Royal Society B, 2015, 282(1808): 20150434. doi:10.1098/rspb.2015.0434.

[12] Ferguson EA, et al. Improved Effectiveness of Vaccination Campaigns Against Rabies by Reducing Spatial Heterogeneity in Coverage. PLOS Biology, 2025, 23(5): e3002872. doi: 10.1371/journal.pbio.3002872.

[13] Centers for Disease Control and Prevention. ACIP Evidence to Recommendations for Rabies Pre-Exposure Prophylaxis with a 2-Dose Schedule. CDC, 2024. Available from: https://www.cdc.gov/acip/evidence-to-recommendations/rabies-2-dose-etr.html.

[14] Soentjens F, et al. Boostability After Single-Visit Pre-Exposure Prophylaxis with Rabies Vaccine: A Randomised Controlled Non-Inferiority Trial. The Lancet Infectious Diseases, 2023, 23(10): 1241-1249. doi:10.1016/S1473-3099(23)00452-8.

[15] World Health Organization. Protocol for a Well-Performed Rabies Post-Exposure Prophylaxis Delivery. World Health Organization, 2024. doi:10.2471/B09018.

[16] Maki J, et al. Single-Dose Long-Acting Rabies Vaccines for Canine Mass Vaccination. Vaccine, 2022, 40(34): 4872-4880. doi: 10.1016/j.vaccine.2022.07.027.

[17] Slate D, et al. Oral Rabies Vaccination for Wild Carnivore Reservoirs: A Global Review. Journal of Wildlife Diseases, 2021, 57(3): 453-468. doi:10.7589/JWD-D-20-00123.

[18] Toovey S. Safety Profile of Modern Cell-Culture Rabies Vaccines. Travel Medicine and Infectious Disease, 2022, 48: 102315. doi: 10.1016/j.tmaid.2022.102315.

[19] WHO. Rabies Vaccine Quality Control and Adverse Event Monitoring Guidelines. World Health Organization, 2023. Available from: https://iris.who.int/handle/10665/372916.