BIBLIOGRAFI RABIES :
TANTANGAN GLOBAL DAN PENDEKATAN ONE HEALTH

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Bogor, Mei 2025

Perpustakaan BRMP Veteriner

DAFTAR ISI

1. **Histopathology and immunohistochemistry findings in kidney and urinary bladder of rabies virus-infected mice,** Sara de Souza Pereira, Cássia Nazaré de Sousa Moraes, Vinicius Pacheco, Érika Dayane Leal Rodrigues, Victor Gabriel Bastos Chaves, Marcella Katheryne Marques Bernal, Roberta Nicole de Oliveira Mota, Ranna Taynara dos Reis Sousa, Adriana Maciel de Castro Cardoso Jaques, Jorge Rodrigues de Sousa, Livia Medeiros Neves Casseb, **Acta Tropica**, Volume 263, 2025, 107550, https://doi.org/10.1016/j.actatropica.2025.107550.

Abstract

Rabies virus (RABV) is a lethal and neglected zoonosis responsible for over 60,000 deaths annually caused by the neurotropic virus Lyssavirus rabies. Although rabies is well-known for its severe nervous system impairment, little is known regarding the specific alterations caused in extraneural organs. Studies suggest an essential involvement of RABV in the kidneys. However, the extent of the pathological damage caused by RABV in this organ remains to be understood. This study describes the histopathological alterations and RABV antigen expression in the kidneys and urinary bladder. Viral immunostaining was observed, suggesting that RABV can successfully infect these tissues. In addition, the main alterations found in the kidneys were edema in the convoluted tubules and in the glomerulus, interstitial inflammation, atrophy of the glomerular tuft, a decrease in Bowman's capsule and Bowman's space, and the accumulation of glycogen in the tubules, which may indicate the effects of inflammation caused by RABV. Therefore, our results showed the importance of understanding the effects of histopathological alterations induced by RABV and the need for more studies concerning the inflammatory action of the virus during the infection.

Keywords: Rabies; Histopathology; Immunohistochemistry; Zoonoses

2. **Generation and selection of novel human-neutralizing single chain variable fragments against rabies virus from immunized phage display libraries,** Apidsada Chorpunkul, Usa Boonyuen, Kriengsak Limkittikul, Wachiraporn Saengseesom, Wallaya Phongphaew, Iyarath Putchong, Montarop Yamabhai, Amin Hajitou, Surachet Benjathummarak, Porntippa Lekcharoensuk, Pannamthip Pitaksajjakul, Pongrama Ramasoota, **Heliyon**, Volume 11, Issue 6, 2025, e42923, https://doi.org/10.1016/j.heliyon.2025.e42923.

Abstract

Rabies remains a deadly infectious disease in tropical areas caused by rabies virus (RABV). Currently, there are limitations in the production and quality control of polyclonal antibodies for postexposure prophylaxis (PEP) for severe patients. Engineered therapeutic monoclonal antibodies (MAbs) are effective therapies against various infectious agents; therefore, we aimed to develop human MAbs against RABV on a single-chain variable fragment (scFv) platform. Immunized scFv libraries were constructed from human peripheral blood mononuclear cells via the pMOD1 phage display system. Diverse VHVLκ and VHVLλ phage-displayed libraries were successfully produced with 2x107 and 5.4x106 clones, respectively. The high affinity and binding specificity of scFvs targeting the RABV glycoprotein were obtained through biopanning and ELISA. Six unique scFv clones presented diverse complementary determining region (CDR) sequences. Interestingly, HuRABVscFv1 and HuRABVscFv2 exhibited rapid fluorescent foci inhibition test (RFFIT)-neutralizing titers above the 0.5 IU/ml protective level. Finally, in silico molecular docking demonstrated that the CDRs of two neutralizing human clones interact mainly with antigenic sites III (HuRABVscFv1) and II (HuRABVscFv2) on the RABV glycoprotein. These scFvs may be candidates for MAb production against RABV to replace traditional PEP in Thailand.

Keywords: Glycoprotein; Infectious disease; Molecular docking; Monoclonal antibodies

3. **Immunogenicity of pre-exposure rabies vaccination comparing number of doses and routes of administration: A systematic review and meta-analyses,** Phaedra Davis, Joshua Montroy, Bryna Warshawsky, Elissa M. Abrams, Leanne Coward, April Killikelly, **Vaccine**, Volume 53, 2025, 126878, https://doi.org/10.1016/j.vaccine.2025.126878.

Abstract

Introduction

Human rabies is rare, though almost universally fatal. Rabies pre-exposure prophylaxis (PrEP) simplifies the post-exposure prophylaxis regimen and may offer some protection from unrecognized rabies exposures. Several different PrEP schedules are recommended by different jurisdictions. The objective of this review was to systematically analyze the impact of schedule and route of administration on immune responses to rabies vaccine in the short-term, long-term, and post-booster, specifically comparing one-, two-, and three-dose schedules, and intramuscular (IM) and 2-site intradermal (ID) routes of administration.

Methods

An existing systematic review was leveraged, and an updated search was conducted in three databases from inception to January 15, 2024. Meta-analyses of seroconversion (≥0.5 IU/mL) and geometric mean titres (GMTs) from direct comparison studies, studies which allowed comparisons of schedules within the same participants/groups of participants, and pooled data across study arms were conducted.

Results

Fifty-four studies met the eligibility criteria. Short-term, most participants who received two or three doses achieved titres ≥0.5 IU/mL regardless of route of administration; seroconversion and GMTs were significantly lower with one-dose schedules. Titres fell over time for all schedules with lower maintenance of seroconversion for two-dose IM schedules than three-dose IM schedules. Following the administration of booster doses, all schedules boosted to GMTs higher than after the primary series resulting in almost 100 % seroconversion, with the lowest seroconversion (98.7 %) for those who received a one 2-site ID dose for their primary vaccination. When comparing IM to 2-site ID administration of rabies vaccine, generally, no significant differences in seroconversion and limited differences in GMTs were observed.

Conclusion

Two- and three-dose schedules had similar seroconversion regardless of route of administration in the short-term and after the booster, but two doses given IM resulted in lower maintenance of seroconversion in the long-term than three doses IM. Seroconversion was significantly reduced with a one-dose schedule in the short- and long-term. Immune responses to all schedules decreased over time, but almost all participants seroconverted following a booster dose. Responses between 2-site ID and IM administration were generally similar with only a few differences observed.

Keywords: Review; Pre-exposure prophylaxis; Seroconversion; Geometric mean titre; Intradermal; Intramuscular

4. **Rabies in humans: A treatment approach,** Cornelis A. De Pijper, Pieter P.A.M. van Thiel, Diederik van de Beek, Matthijs C. Brouwer, Eleonora Aronica, Nicole P. Juffermans, Ron A.A. Mathôt, Corine H. GeurtsvanKessel, Janke Schinkel, Menno D. de Jong, Martin P. Grobusch, Abraham Goorhuis, **Travel Medicine and Infectious Disease**, Volume 64, 2025, 102813, https://doi.org/10.1016/j.tmaid.2025.102813.

Abstract

Background

Only few rabies survivors have been described in the medical literature, of whom most suffered severe neurological sequelae. Published treatment protocols have not been applied successfully. Yet, experimental treatments may be of benefit when factors associated with survival are present. Here, we describe two patients who were hospitalised at Amsterdam UMC with clinical rabies and who died despite experimental treatments.

Methods

We describe the clinical course and medical decisions in the treatment of two rabies patients at our hospital and compared this approach with published data on the treatment of clinical rabies, depending on the presence or absence of prognostic factors associated with survival, and regarded this information in the context of clinical practice.

Results

The most important factor associated with survival - the presence of high antibody titres in serum or cerebrospinal fluid (CSF) at the time of diagnosis - was not present in either of the two cases at our hospital. In addition to supportive treatment, both of our patients were treated unsuccesfully with a novel treatment approach with intrathecal and intravenous monoclonal rabies antibodies, which barely increased serum and CSF antibody levels.

Conclusions

Higher-dosed treatments with monoclonal antibodies in serum may be needed to yield an effect. Any experimental treatment may be most promising in patients who have other factors associated with survival. In the absence of these, initiation of palliative care still seems to remain the most rational strategy.

Keywords: Rabies; Rabies virus; Lyssavirus; Milwaukee protocol; Treatment

5. **Rabies exposure in international travellers: Experience from a single travel clinic in Paris, France, 2018–2022,** Patrick Hochedez, Kaoutar Jidar, Fabien Taieb, Oula Itani, Ghania Benabdelmoumen, Perrine Parize, Hervé Bourhy, Paul-Henri Consigny, Philippe Poujol, **Travel Medicine and Infectious Disease**, Volume 64, 2025, 102821, https://doi.org/10.1016/j.tmaid.2025.102821.

Abstract

Background

Rabies is a vaccine-preventable zoonotic disease which causes thousands of deaths every year, mainly in Asia and Africa, and dogs are the main source of human cases. Although rabies is rare in international travellers, rabies exposure is relatively frequent and the number of travellers seeking post-exposure treatment may rise as international travel continues to increase. We aimed to better understand the characteristics of travellers exposed to rabies abroad, in order to deliver targeted advice and rabies vaccination during pre-travel clinics.

Methods

During 2018–2022, we studied all returning travellers who attended a single travel clinic in Paris, France, for animal exposures abroad and requiring rabies post-exposure prophylaxis (n = 2916).

Results

During the study period, 2916 returning travellers were included, and 59.7 % of exposures occurred in Southeast Asia (mainly Thailand and Indonesia) and North-Africa. Dogs were predominantly responsible for exposures, but the animals involved varied significantly according to the region visited and the age of the traveller. Monkey exposures were more frequently reported in Asia, and cat exposures in North Africa and among children. Exposures were reported as unprovoked in 22.9 % of cases, and 91 % of travellers had not received anti-rabies vaccines before travelling.

Conclusions

Travellers to rabies endemic countries should benefit from more targeted information based on the region visited, the animals they are likely to encounter, and the age of the travellers. Critically, they should be counselled on the importance of avoiding contact with animals, the long-lasting benefit of pre-travel rabies vaccination, and the need for adequate post-exposure prophylaxis.

Keywords: Animal bite; Rabies exposure; Post-exposure prophylaxis; Rabies immunoglobulin; Travel medicine

6. **Rabies Post-Exposure Treatment in Metropolitan Sydney Residents, 2013-2023: A Retrospective Case-Series Analysis,** Alice Self, Troy McNeill, Andrew Ingleton, Thomas, R.Browne, LeenaGupta, **Travel Medicine and Infectious Disease**, Volume 65, 2025, 102856, https://doi.org/10.1016/j.tmaid.2025.102856.

Abstract

Background

The nature and frequency of rabies and Australian Bat Lyssavirus (ABLV) exposures requiring post-exposure treatment (PET) in metropolitan Sydney residents has not previously been described. We assessed the trends in PET use in this population, the nature of exposures, geographic distribution, and timeliness and completeness of PET provided, comparing between local and overseas exposures.

Methods

A retrospective case series analysis of potential rabies and ABLV exposures in residents of Sydney Local Health District reported to the public health unit between 1 January 2013 and 31 December 2023.

Results

Data were available for 595 exposed persons; 477 (80%) were overseas exposures, and 118 (20%) were local ABLV exposures. PET was administered in 587 (99%) exposures. Overseas exposures were mostly due to bites from monkeys, and the majority occurred in Asia (92%), specifically in Indonesia. Local exposures were mostly due to megabat injuries. Bat testing occurred following 25% of local exposures, with a 20% ABLV positivity rate. Inadequate wound management was reported in 45% of exposures. PET was markedly delayed (commenced greater than 14 days after exposure or a mid-schedule delay) in 26% of overseas and 7% of local exposures and incomplete in 15% of overseas and 4% of local exposures. Only 8% of exposed persons received pre-exposure prophylaxis (PrEP).

Conclusion

Cost reduction strategies and measures to improve adherence and accessibility to PET, such as prepositioned stock and standing orders, should be explored. Improving public health risk communication about animal avoidance and appropriate treatment if exposed may also reduce delayed and incomplete PEP. Australian travelers to rabies-endemic countries should be routinely counselled on the benefits of PrEP.

Keywords: Rabies; Australian Bat Lyssaviruses; Post-exposure treatment; Rabies vaccine; Rabies immunoglobulin

7. **Fractional optimal control problem modeling bovine tuberculosis and rabies co-infection,** Boubacar Diallo, Munkaila Dasumani, Jeconia Abonyo Okelo, Shaibu Osman, Oumar Sow, Nnaemeka Stanley Aguegboh, Walter Okongo, **Results in Control and Optimization**, Volume 18, 2025, 100523, https://doi.org/10.1016/j.rico.2025.100523.

Abstract

Bovine tuberculosis (bTB) and rabies are eminent zoonotic afflictions that significantly impact global economic stability and public health, with pronounced effects in developing nations. These diseases continuously pressure public health systems and obstruct efforts to improve livestock productivity and export capabilities. Studying the joint dynamics of bTB and rabies involves notable mathematical complexities due to the differences in their transmission mechanisms. Moreover, while there is some overlap among animal populations at risk for bTB and rabies, the exact proportion of animals susceptible to both diseases remains unspecified. In this work, we provide a simplified fractional-order optimal control model that integrates the dynamics of bTB and rabies co-infection. We determine the basic reproduction numbers for bovine tuberculosis R0T and rabies (R0R), as well as the overall reproduction number for the model $R=\max\{R0T,R0R\}$. The qualitative analysis reveals that when $R<1$, the disease-free equilibrium is locally asymptotically stable. We implement optimal control analysis to identify the best strategies for preventing each disease separately and their co-infection. The optimal control problem is solved numerically utilizing a forward–backward predict-evaluate correct-evaluate (PECE) algorithm implemented in Matlab software. The simulation results show that strategy E (i.e., implementation of all optimal controls) is significantly more effective in managing bovine tuberculosis but less effective in controlling rabies and co-infection. Conversely, strategy B (i.e., applying vaccination and removal of optimal controls for animals affected by rabies) provides satisfactory optimal control results across the three infection scenarios.

Keywords: Fractional optimal control problem; Rabies; Bovine tuberculosis; Co-infection

8. **Rabies vaccines: Journey from classical to modern era,** Bushra Khan, Nidhi Shrivastava, Naheed Parveen Sheikh, Pramod Kumar Singh, Hem Chandra Jha, Hamendra Singh Parmar, **Veterinary Vaccine**, Volume 4, Issue 1, 2025, 100105, https://doi.org/10.1016/j.vetvac.2025.100105.

Abstract

Rabies, caused by the neurotropic rabies virus, remains a significant public health concern worldwide. It remains a deadly zoonotic disease with a near 100 % fatality rate once clinical symptoms manifest, causing about 59,000 deaths annually, of which 59.6 % occur in Asia and 36.4 % in Africa. Dog-mediated rabies accounts for over 99 % of human cases. This review provides a comprehensive overview of rabies, covering its epidemiology, pathogenesis, Etiology, and developments in rabies vaccines. Once the virus enters the body through the bite of an infected animal it travels via peripheral nerves to the central nervous system, leading to fatal encephalitis if left untreated. Vaccination of domestic animals plays a pivotal role in preventing transmission to humans. Post-exposure prophylaxis (PEP) remains the cornerstone of rabies prevention in individuals exposed to potentially infected animals, comprising rabies vaccine and Rabies immunoglobulin administration. Advances in molecular virology have shed light on the pathogenesis of rabies, revealing the intricate interactions between the virus and the host immune system. Despite decades of research, treatment options for established rabies infection remain limited, emphasizing the importance of preventive measures. Experimental therapies, including monoclonal antibodies and novel antiviral agents, promise to improve outcomes in rabies patients. Regardless of the established efficacy of rabies vaccines, challenges remain in ensuring widespread accessibility and coverage, particularly in resource-limited regions. Strategies to enhance pre-exposure prophylaxis with affordable vaccine delivery are essential for achieving global rabies control and elimination goals, underscoring the need for sustained surveillance, vaccination, and public awareness efforts. Continued research into the virology and immunology of rabies is essential for the development of novel interventions to combat this deadly disease.

Keywords: Rabies vaccines; Post-exposure prophylaxis (PEP); Pre-exposure prophylaxis (PrEP); Dog mediated; Zoonotic

9. **A persona-based exploration of rabies post-exposure prophylaxis seeking behavior and its implication for communication strategic planning: Evidence from Thailand,** Jitjayang Yamabhai, Patoo Cusripituck, Teerawan Mingbualuang, Nareerat Sangkachai, Wimwiga Sakchainanon, Chanatda Tungwongjulaniam, Onphirul Yurachai, Ratana Theerawat, Anuwat Wiratsudakul, **One Health**, Volume 20, 2025, 100980, https://doi.org/10.1016/j.onehlt.2025.100980.

Abstract

Rabies is a lethal zoonotic illness that claims over 59,000 lives annually. However, this fatality can be avoided by postexposure prophylaxis (PEP). This study aimed to identify and characterize different personas of individuals regarding their PEP-seeking behavior and develop tailored communication strategies to encourage PEP adoption among these distinct groups effectively. We categorized our subjects, residing in two districts of Chonburi province, Thailand, into three groups: (i) individuals with a history of dog bites who underwent PEP; (ii) individuals bitten by dogs who did not receive PEP; and (iii) individuals who had never been bitten. Subsequently, we employed an empathy map, a visual method, and a customer journey map to better understand the participants' experiences and perceptions. A total of 38 individuals were interviewed. We categorized the participants into three distinct personas: positive, neutral, and negative trends. Individuals classified within the positive trend strongly advocate for seeking rabies vaccines in the event of a dog bite. Meanwhile, individuals who have a neutral inclination are more likely to contemplate getting vaccinated following a dog bite, particularly if the injury is substantial. Those with a negative trend demonstrate a notable lack of attention or concern toward preventing rabies. A lack of attention to the potential severity of the issue characterizes their attitude. Notably, nearly half (44.74 %; 17/38) of the individuals involved in the study indicated utilizing interpersonal communication, followed by digital platforms (42.11 %; 16/38) and traditional communication channels (10.52 %; 5/38). Tailoring communication modalities to suit each specific group is crucial for effective outreach.

Keywords: Communication; Community; Persona; Postexposure prophylaxis; Rabies

10. **A fractional-operator approach for unraveling rabies disease dynamics in animal population,** Marya Zainab, Adnan Aslam, Takasar Hussain, Muhammad Ozair, Ahmed M. Shehata, Kottakkaran Sooppy Nisar, M. Abdalla, **Alexandria Engineering Journal**, Volume 124, 2025, Pages 540-549, https://doi.org/10.1016/j.aej.2025.03.082.

Abstract

Rabies remains a significant public health threat. It necessitates robust mathematical frameworks to understand its transmission dynamics and control strategies. In this work. we develop a novel fractional order mathematical model for rabies disease considering Atangana–Baleanu fractional operator to better capture the memory and hereditary properties of the disease spread. The existence and uniqueness of solutions are established by applying rigorous analytical techniques, ensuring the model's well-posedness. Additionally, a numerical scheme developed by Toufik and Atangana has been applied to solve the fractional order system efficiently. Numerical simulations illustrates the impact of fractional dynamics on disease propagation providing deeper insights into rabies control mechanisms. The results highlights the advantage of fractional modeling in capturing complex epidemiological behaviors compared to classical integral order models. The findings contribute to the ongoing efforts in developing more accurate predictive measures for the Rabies control and prevention.

Keywords: Rabies; Deterministic model; Existence of solutions; Fractional operators

11. **Mass rabies exposure of veterinary health care workers in Germany: Management, immune response, and tolerability of post exposure-prophylaxis**, Lennart Lemmermann, Jonathan Remppis, Sabine Bélard, Florian Steiner, **One Health**, Volume 20, 2025, 100978, https://doi.org/10.1016/j.onehlt.2025.100978.

Abstract

Background

Rabies is a fatal zoonotic disease caused by Rabies lyssavirus, primarily transmitted through dog bites. In 2008, Germany was declared free from terrestrial rabies by the WOAH. However, illegal pet imports can still lead to rabies exposure, as seen in the 2021 case of a rabid puppy illegally imported to Germany, resulting in a mass exposure incident.

Methods

This retrospective study assessed the post-exposure management of 39 veterinary clinic staff exposed to the rabid puppy, focusing on the practicability, immunogenicity, and tolerability of post-exposure prophylaxis (PEP). Data was collected from patient records and for follow-up by phone using standardized case record forms, entered into an Excel database, and analyzed descriptively. Ethics approval was obtained from the Ethics Committee of the University of Tübingen (8452022BO2).

Results

Exposed individuals received varying PEP regimens based on vaccination status and exposure level, including possible aerosol exposure. Most followed the Essen-Scheme, with some receiving human rabies immune globulin (hRIG). All developed protective antibody titers, and adverse reactions were generally mild.

Conclusion

This case highlights challenges in rabies mass exposure management and emphasizes needs for continued preparedness, resource allocation and education about rabies, even in regions considered rabies-free.

Keywords: Rabies; Mass exposure; Post-exposure prophylaxis; Illegal pet trade; Germany; Vaccination strategies

12. **Real-world evidence of rabies post-exposure prophylaxis in Serbia: Nation-wide observational study (2017–2019),** Pavle Banović, Dragana Mijatović, Verica Simin, Nenad Vranješ, Eleftherios Meletis, Polychronis Kostoulas, Dasiel Obregon, Alejandro Cabezas-Cruz, **Travel Medicine and Infectious Disease**, Volume 58, 2024, 102697, https://doi.org/10.1016/j.tmaid.2024.102697.

Abstract:

Background

Rabies remains a deadly zoonotic disease, primarily prevalent in Eastern European countries, with a significant global burden in Asia and Africa. Post-exposure prophylaxis (PEP) is critical to prevent clinical rabies. Serbia, a country with a relatively low animal rabies incidence, has been implementing a 4-dose Essen PEP regimen for 13 years. This real-world study aimed to assess the effectiveness of the 4-dose Essen regimen, considering demographic and clinical factors, after WHO Category III exposure.

Method

The study included 601 patients who received the 4-dose Essen PEP and 79 who received an additional 5th dose.

Results

Age emerged as a critical factor influencing seroconversion rates after the 4-dose regimen, with older individuals exhibiting lower RVNA titers. Logistic regression indicated a 3.18% decrease in seroconversion odds for each added year of age. The Cox proportional hazards mixed model highlighted age-related risks, with age groups 45–60 and 75–92 at the highest risk of non-seroconversion. Human Rabies Immune Globulin (HRIG) administration was associated with lower RVNA values after the 4-dose regimen, suggesting interference with vaccine immunogenicity among people who received larger doses of HRIG.

Conclusions

This study provides valuable real-world evidence for rabies PEP in a non-homogeneous population with potential comorbidities. The results underscore the importance of optimizing PEP strategies, particularly in older individuals, and reconsidering HRIG dosing to improve seroconversion rates.

Keywords: Rabies; Post-exposure prophylaxis; Essen regimen; Seroconversion; Rabies virus-neutralizing antibodies

13. **Mechanism of action of phthalazinone derivatives against rabies virus,** Victoire Perraud, Bart Vanderhoydonck, Guillaume Bouvier, Guilherme Dias de Melo, Amuri Kilonda, Mohamed Koukni, Dirk Jochmans, Sophie Rogée, Youcef Ben Khalifa, Lauriane Kergoat, Julien Lannoy, Tina Van Buyten, Nadia Izadi-Pruneyre, Patrick Chaltin, Johan Neyts, Arnaud Marchand, Florence Larrous, Hervé Bourhy, **Antiviral Research**, Volume 224, 2024, 105838, https://doi.org/10.1016/j.antiviral.2024.105838

Abstract

Rabies, a viral zoonosis, is responsible for almost 59,000 deaths each year, despite the existence of an effective post-exposure prophylaxis. Indeed, rabies causes acute encephalomyelitis, with a case-fatality rate of 100 % after the onset of neurological clinical signs. Therefore, the development of therapies to inhibit the rabies virus (RABV) is crucial. Here, we identified, from a 30,000 compound library screening, phthalazinone derivative compounds as potent inhibitors of RABV infection and more broadly of Lyssavirus and even Mononegavirales infections. Combining in vitro experiments, structural modelling, in silico docking and in vivo assays, we demonstrated that phthalazinone derivatives display a strong inhibition of lyssaviruses infection by acting directly on the replication complex of the virus, and with noticeable effects in delaying the onset of the clinical signs in our mouse model.

Keywords: Antiviral therapy; Rabies; Replication complex; Phthalazinone; In silico drug-target docking

14. **An observational cohort study,Travel Medicine and Infectious Disease, Rabies knowledge gaps and risk behaviour in Dutch travellers** **:** Lisanne A. Overduin, Jan Pieter R. Koopman, Corine Prins, Petra H. Verbeek-Menken, Cornelis A. de Pijper, Fiona Heerink, Perry J.J. van Genderen, Martin P. Grobusch, Leo G. Visser, **Travel Medicine and Infectious Disease**, Volume 60, 2024, 102739, https://doi.org/10.1016/j.tmaid.2024.102739.

Abstract

Background

Travellers visiting rabies-endemic countries are at risk of rabies infection. Assessing travellers' knowledge and risk perception of rabies and risk behaviour during travel can help identify knowledge gaps and improve pre-travel risk education.

Methods

Cohort study in Dutch adult travellers, using two surveys: one before travel to assess knowledge and perception of rabies, and one after return to identify risk behaviour during travel.

Results

The pre-travel and post-travel survey were completed by 301 and 276 participants, respectively. 222 participants had travelled to a high-risk rabies-endemic country. 21.6 % of the participants scored their rabies knowledge as poor. Some participants were unaware cats or bats can transmit rabies (26.6 % and 13.6 %, respectively), or that post-exposure prophylaxis (PEP) is required for certain exposures such as skin abrasions without bleeding or licks on damaged skin (35.5 % and 18.9 %, respectively), while 27.9 % of participants did not know PEP needs to be administered within one day. 115 participants (51.8 %) reported any form of contact with any animal during travel. Two participants reported animal exposure, of which one took adequate PEP measures. Risk factors for animal contact abroad were regularly touching cats or dogs at home or abroad, longer travel duration, having pets during childhood and being an animal lover.

Conclusions

Pre-travel rabies risk education currently does not meet travellers' needs, which is reflected in knowledge gaps and engagement in risk behaviour during travel. During pre-travel health advice, avoiding animal contact abroad should be emphasized, and additional education is required about indications for PEP.

Keywords: Rabies; Risk education; Compliance with advice; Travel

15. **Efforts of rabies elimination with a One Health approach and SARE tools in Ethiopia,** Gashaw Adane Erkyihun, Sisay Getachew Deressa, Wubishet Zewdie Wakene, Fikru Regassa Gari, **Decoding Infection and Transmission**, Volume 2, 2024, 100028, https://doi.org/10.1016/j.dcit.2024.100028.

Abstract

Rabies is a viral zoonosis which affects nearly every region of the world. Once symptoms appear, the disease is 100 % fatal, although it is 100 % preventable through vaccination. Human rabies is typically caused by virus transmitted from the bite of an infected dog. Rabies results in significant economic costs and human fatalities, with children being disproportionately affected. Numerous countries have embraced a global goal to eliminate dog-mediated human rabies by 2030. In line with this, Ethiopia has integrated a global prevention and elimination strategy into its national program, and is implementing various interventions. During 2022 and 2023, the Ministry of Agriculture, in partnership with One Health collaborators, vaccinated over 350,000 domestic dogs. Documenting these efforts and best practices is essential for sharing ongoing control and elimination experiences with other countries. This review outlines the burden and impact of rabies, the current status of the Ethiopian 2030 rabies control and elimination program, and its achievements and challenges. The review also highlights the current state of stakeholder collaboration and coordination efforts.

Keywords: Achievements; Challenges; Elimination; Ethiopia; Mass dog vaccination; Rabies

16. **Resveratrol inhibits rabies virus infection in N2a cells by activating the SIRT1/Nrf2/HO-1 pathway,** Qian Liu, Qing He, Xiaoyan Tao, Pengcheng Yu, Shuqing Liu, Yuan Xie, Wuyang Zhu, **Heliyon**, Volume 10, Issue 17, 2024, e36494, https://doi.org/10.1016/j.heliyon.2024.e36494.

Abstract

Rabies is a highly lethal infectious disease with no existing treatment available, thus investigating effective antiviral compounds to control rabies virus (RABV) infection is of utmost importance. Resveratrol is a natural phenolic compound that, as a phytoalexin, exhibits several biological activities, including antiviral activity. In this study, we evaluated the inhibitory effect of resveratrol on RABV infection and investigated its molecular antiviral mechanism. We found that resveratrol significantly inhibited RABV infection, including the phases of adsorption, replication, and release, and also directly inactivated RABV and inhibited its infectivity. However, resveratrol had no significant effect on RABV internalization. Resveratrol also reduced RABV-induced oxidative stress, specifically reactive oxygen species and malondialdehyde levels. Western blotting analysis revealed that resveratrol enhanced antioxidant signaling via the SIRT1/Nrf2/HO-1 pathway and inhibited viral replication. Viral infection was enhanced after SIRT1 knockdown, which inhibited the SIRT1/Nrf2/HO-1 antioxidant signaling pathway, suggesting that this pathway plays an important role in RABV replication. Overall, resveratrol prevented the adsorption, replication, and release of RABV and directly inactivated RABV, but failed to inhibit RABV internalization. Furthermore, resveratrol activated the SIRT1/Nrf2/HO-1 pathway to inhibit RABV replication and suppressed RABV-induced oxidative stress. These findings highlight the therapeutic potential of resveratrol for fighting RABV infections.

Keywords: Rabies; Rabies virus; Resveratrol; SIRT1; Oxidative stress

17. **Immunogenicity of 4-dose Essen intramuscular regimen for rabies post-exposure prophylaxis: A multi-center cross-sectional study in China,** Qisheng Hou, Si Liu, Cheng Liu, Xu Wang, Jirong Shi, Qingjun Chen, Xinjun Lv, Zhenggang Zhu, Chuanlin Wang, Wenwu Yin, **Travel Medicine and Infectious Disease**, Volume 60, 2024, 102735, https://doi.org/10.1016/j.tmaid.2024.102735.

Abstract

Background

The 4-dose Essen intramuscular (IM) regimen for rabies post-exposure prophylaxis (PEP) has been recommended by Advisory Committee on Immunization Practices (ACIP) and World Health Organization (WHO), but the large-sample clinical evidence is still limited.

Method

Rabies virus neutralizing antibodies of 11,752 patients were detected from 409 rabies prevention clinics in 27 provinces in China. Patients with serum collected before or no later than 1 h after injection on the day of the fifth dose (day 28) of 5-dose Essen regimen were included in Group A to observe the immune efficacy of 4-dose Essen IM regimen, and patients with serum collected 14–28 days after injection of the fifth dose were included in Group B to observe the immune efficacy of 5-dose Essen IM regimen.

Results

Finally, 2351 cases met the inclusion and exclusion criteria, including 2244 cases in Group A and 107 cases in Group B. The antibody titer of Group A was higher than that of Group B [12.21 (4.15, 32.10) IU/ml vs. 9.41 (3.87, 27.38) IU/ml] ($P = 0.002$). In Group A, the median antibody titers were 4.01IU/ml, 11.63IU/ml and 29.46IU/ml in patients vaccinated with purified hamster kidney cell vaccine (PHKCV), purified Vero cell vaccine (PVRV), and human diploid cell rabies vaccine (HDCV), respectively, with statistical significance ($P < 0.001$).

Conclusions

The 4-dose Essen IM regimen could provide satisfactory immune effect, and HDCV induced higher antibody titer than PHKCV or PVRV.

Keywords: Rabies; Post-exposure; Prophylaxis; Neutralizing antibody; 4-Dose Essen

18. **Cross-correlation and time series analysis of rabies in different animal species in Nepal from 2005 to 2018,** Swochhal Prakash Shrestha, Warangkhana Chaisowwong, Mukul Upadhyaya, Swoyam Prakash Shrestha, Veerasak Punyapornwithaya, **Heliyon**, Volume 10, Issue 3, 2024, e25773, https://doi.org/10.1016/j.heliyon.2024.e25773.

Abstract

Rabies is a fatal zoonotic disease, resulting in human and livestock deaths. In Nepal, animal rabies has posed a significant challenge to public health. Because animals are the primary source of rabies in humans, a better understanding of rabies epidemiology in animals is necessary. The objectives of this study were to determine the correlation between rabies occurrences in dogs and livestock animals and to detect the trends and change points of the disease using longitudinal data. The nationwide rabies dataset from 2005 to 2018 was analyzed using cross-correlation, multiple change points, and time series methods. Autoregressive Integrated Moving Average (ARIMA) and Neural Network Autoregression (NNAR) were applied to the time series data. The results show a positive correlation between canine rabies and livestock rabies occurrences. Three significant change points were detected in the time series data, demonstrating that the occurrences were high in the initial years but stabilized before peaking to an upward trend in the final years of the study period. Nonetheless, there was no seasonality pattern in rabies occurrences. The most suitable models were ARIMA (2,1,2) and NNAR (5,1,4) (12). Based on the study findings, both locals and tourists in Nepal need to have enhanced awareness of the potential dangers posed by rabies in canines and livestock. This study offers much-needed insight into the patterns and epidemiology of animal rabies which will be helpful for policymakers in drafting rabies control plans for Nepal.

Keywords: Cross-correlation; Forecasting; Nepal; Rabies; Time series

19. **The safety, pharmacokinetics and neutralizing activity of recombinant human anti-rabies monoclonal antibody NM57 injection (rhRIG, Ormutivimab) in combination with rabies vaccination in Chinese healthy adults: A phase Ib randomized, double-blind, parallel-controlled clinical study,** Yin Yin, Min Jia, Yufeng Li, Wei Zhao, Shuhong Chen, Peiyuan Huo, Qinghua Zhao, Lan Yu, Cha Wang, Yirui Ma, Meixia Wang, Jing Zhang, **Travel Medicine and Infectious Disease**, Volume 63, 2025, 102792, https://doi.org/10.1016/j.tmaid.2024.102792.

Abstract

Background

The combination of passive immune agents (human rabies immune globulin (HRIG) and equine rabies antiserum (ERA)) with vaccines are effective measures for preventing the onset of rabies post exposure. However, ERA and HRIG have potential risks of serum allergic reactions and blood-transmitted infectious diseases. This study compared the safety, pharmacokinetics and neutralizing activity of recombinant human anti-rabies monoclonal antibody NM57 injection (rhRIG, Ormutivimab) and HRIG in combination with rabies vaccine and vaccine alone.

Method

This randomized, double-blind, parallel-controlled Phase Ib clinical study was conducted in healthy Chinese population to evaluate the safety, pharmacokinetics, and neutralizing activity of rhRIG at dosages of 20IU/kg and 40IU/kg in combination with vaccines, and to compare the neutralizing activity of rhRIG + vaccine with that of HRIG + vaccine and vaccine alone. 72 healthy participants divided into 6 groups of 12 individuals.

Results

The rhRIG at dosages of 20IU/kg and 40IU/kg in combination with vaccines showed favorable safety and presented the pharmacokinetic property of linear elimination. The antibody neutralizing activity of rhRIG has the same level as HRIG in combination with vaccines. The rhRIG did not affect the long-term protective effect of the vaccine.

Conclusions

The rhRIG could provide immediate immune protection at the wound site and producing earlier protection during the window period before the rabies vaccine established active immunity. Therefore, it is recommended to continue to evaluate the safety and antibody neutralizing activity of rhRIG (20 and 40IU/kg) in combination with the vaccine in Phase II clinical trials.

Trials registration

Keywords: Ormutivimab; rhRIG; Monoclonal antibodies; Rabies; Passive immunization

20. **Dynamics of rabies disease model under Atangana–Baleanu fractional derivative,** Marya Zainab, Adnan Aslam, Takasar Hussain, Muhammad Ozair, **Alexandria Engineering Journal**, Volume 115, 2025, Pages 390-400, https://doi.org/10.1016/j.aej.2024.11.099.

Abstract

In this work, animal rabies disease is explored through a nonlinear mathematical model. The necessary conditions under the fractional operator is considered for the existence and uniqueness of solutions. The parameters are estimated through the model calibration with the confirmed cases of rabies in cattle, from 1996 to 2002, in India. Numerical results portray that fractional order gives good fit to the real data in comparison with the classical order. Moreover, different control strategies, based on the sensitivity of parameters, are discussed for the controlling and reduction of the infection.

Keywords: Rabies; Mathematical model; Existence of solutions; Parameter estimation; Control policies

21. **Contribution of artificial intelligence for understanding animal rabies epidemiology in Morocco: What are the perspectives of an innovative and predictive approaches?,** Ilham Ahamjik, Ayman Agbani, Mounia Abik, Mounir Khayli, Naima Galzim, Jaouad Berrada, Mohammed Bouslikhane, **One Health**, Volume 19, 2024, 100874, https://doi.org/10.1016/j.onehlt.2024.100874.

Abstract

Rabies is a major zoonotic disease legally notifiable in Morocco and elsewhere. Given the burden of rabies and its impact on public health, several national control programs have been implemented since 1986, without achieving their expected objectives. The aim of this study was to design a predictive analysis of rabies in Morocco. The expected outcome was the construction of probabilistic diagrams that can guide actions for the integrated control of this disease, involving all stakeholders, in the country. Such modeling is an essential step in operational epidemiology to optimize expenditure of public funds allocated to the integrated strategy for fighting this disease. The methodology employed combined the use of geospatial analysis tools (kriging) and artificial intelligence models (Machine Learning). In order to investigate the link between the risk of rabies within a territorial municipality (commune) and its socio-economic situation,

the following data were analyzed: (1) health data: reported animal cases of rabies between 2004 and 2021 and data obtained through the ArcGIS kriging tool (Geospatial data); (2) demographic and socio-economic data. We compared several Machine Learning models. Of these, the “Imbalanced-Xgboost” model associated with kriging yielded the best results. After optimizing this model, we mapped our results for better visualization. The obtained results complement and consolidate previous study in this field with greater accuracy, showing a strong correlation between a commune's socio-economic status, its geographical location and its risk level of rabies. From this, 399 out of the 1546 communes have been identified as high-risk areas, accounting for 25.8% of the total number of communes. Under this risk-based approach, the results of these analyses make it practical to take targeted decisions for rabies prevention and control, as well as canine population control, in a territorial commune according to its risk level. Such an approach allows obvious optimized distribution of financial resources and adaptation of the control actions to be taken. The study highlights also the importance of using innovative technologies to refine epidemiological approaches and fill gaps in field data. Through this study, we hope to contribute to eradication of rabies in Morocco by providing reliable data and practical recommendations for control actions against rabies.

Keywords: Rabies; Epidemiology; Public health; Morocco; Kriging; Artificial intelligence; Machine learning

22. **Effect of telephone reminders on adherence to anti-rabies vaccine amongst animal bite patients in North India: A randomised, single-blind, parallel-group, single-centre, interventional superiority trial**, Aman Dev Singh, Simmi Oberoi, Neha Kaler, Namrata Singh, Japneet Kaur, Ananya Vig, **IJID Regions**, Volume 12, 2024, 100386, https://doi.org/10.1016/j.ijregi.2024.100386.

Abstract

Objectives

Rabies is a highly infectious viral zoonotic disease of the central nervous system with a near 100% fatality rate. Vaccine adherence is an integral part of achieving effective treatment. India accounts for 27% of the global deaths from rabies yearly. Rabid dog bites are responsible for 99% of these deaths. This study aimed to assess the effect of reminder calls on compliance with the anti-rabies vaccine among animal bite patients.

Methods

An interventional, randomised, single-blinded, parallel-group, single-centre study was conducted at the Anti Rabies Clinic, Rajindra Hospital, Government Medical College, Patiala, a city located in Punjab, India, with a population of approximately 19 lakhs. A sample of 400 patients was enrolled and divided into two groups by lottery method. After obtaining written and informed consent from patients, data were collected using a validated pre-tested, semi-structured proforma. The intervention group received reminder calls before each dose. At the end of the study, complete information regarding compliance was obtained from both groups and analysed.

Results

The median age group of the animal bite patients was 21-40 years, with most being male (69.50%). Most of the bites were on the lower extremities (64.0%), followed by the upper extremities (29.0%) and the face (3.25%). Out of 153 patients who delayed the dose, 137 (89.54%) delayed a single dose. The 4th dose on the 28th day was the most frequently delayed dose (75.16%). Reminder calls increased the vaccine compliance rate from 53.5% in the non-intervention group to 70% in the intervention group (adjusted odds ratio=2.28; P=0.0002). There was no effect of gender, area, educational qualification, or marital status on the compliance.

Conclusions

Reminder calls were found to have significant effect on the adherence to the anti-rabies vaccine. This simple, cost-effective, and patient-friendly intervention must be integrated within the health care system to ensure timely and complete administration of the anti-rabies vaccine to reduce the risk of rabies.

Keywords: Call reminder; Compliance; Vaccination; Randomised trial

23. Dog demography and ecology with reference to rabies in the Amhara region, Ethiopia, Liuel Yizengaw Adnie, Wudu Temesgen Jemberu, Adane Bahiru Woreta, Adugna Berju, Araya Mengistu, Zeleke Tesema Wondie, Wassie Molla, Sefinew Alemu Mekonnen, **Heliyon**, Volume 11, Issue 1, 2025, e41582, https://doi.org/10.1016/j.heliyon.2024.e41582.

Abstract

Knowledge of domestic dog ecology and demography has been recognized as central to the design of an effective rabies control program. The study was conducted to assess owned dogs' ecology and demography and to identify predictors associated with dog ownership and rabies occurrence in the Amhara region, Ethiopia.

Method

ology: The study employed dog census and questionnaire surveys of 907 households selected using a multistage sampling technique from six rural and six urban districts of the Amhara region, Ethiopia. The ecology and demography of owned dogs in the selected areas were recorded and described using descriptive statistics. Mixed-effect logistic regression models were used to identify factors associated with dog ownership and rabies occurrence.

Results

A total of 6609 dogs were estimated from 42 kebeles in the 12 study districts. The male-to-female ratio of dogs was 1.7:1.0, and the mean age of dogs was 3.2 years. The proportion of households who owned at least one dog was 5.9 %. The average number of dogs per dog-owned household was 1.3. Dog to household ratio was 1.0:13.0, and dog to human ratio was 1.0:48.5. The majority of the dog owners (97 %) keep dogs for home guard and livestock herding. Only 57 % of the dogs were confined, and 16 % of them were vaccinated. Ninety-one percent of the dog owners did not practice neutering and spaying for dog population control. Religion, livestock ownership pattern, and occupation were associated with dog ownership ($p < 0.05$). Community residence and age of respondents were associated with rabies occurrence ($p < 0.05$), while zone was associated with both dog ownership and rabies occurrence at p-value <0.05.

Conclusions

The study indicated a low dog population relative to humans, which might make dog-based rabies control manageable. But at the same time, most dogs were not properly managed (confined and vaccinated), which calls for more awareness about responsible dog ownership to reduce zoonotic disease risk, including rabies. Generally, the study provides useful information about the demography and ecology of owned dogs in relation to rabies for making proper and effective rabies control strategies and is important to design the spatial distribution of rabies vaccination in dogs. However, as the study did not include stray dogs, which have great contributions to the spread of rabies, the information should be used with this caveat into consideration.

Keywords: Amhara; Demography; Dogs; Ecology; Ethiopia; Rabies

24. **Influencing factors and prediction of neutralizing antibodies in post-exposure rabies vaccine recipients,** Chunping Huang, Ling Zhang, Xiaoyue Shan, Siwei Tan, Haipeng Ye, Chengjian Cao, Lei Zhang, **Heliyon**, Volume 10, Issue 15, 2024, e35673, https://doi.org/10.1016/j.heliyon.2024.e35673.

Abstract

To assess the factors that influencing the persistence of virus neutralizing antibody (VNA), and to establish prediction models to provide the appropriate timing for booster administration, a cohort of post-exposure rabies vaccine recipients was investigated. The VNA determined records from 2019 to 2023 and interrelated factors were analyzed, including gender, age, rabies immunoglobulin (RIG) administration, vaccine products, vaccination schedule, and vaccination intervals etc. The geometric mean of VNA titre within 1 month after primary vaccination with 2-1-1 schedule was statistically higher than that with 5-dose course (P = 0.031). The interaction between exposure and vaccination schedule was observed on primary vaccination, which showed that a decrease of 19.74 % (95 % CI: 5.99%–64.95 %, P = 0.008) of VNA titre among vaccinee with 5-dose and exposure III. Individuals with RIG administration produced lower VNA titres than those without RIG administration (P = 0.001). Vaccine products (Chengda, P = 0.015; human diploid cell, P = 0.026) and re-exposed time (P = 0.000) exhibited independent effects following booster vaccination. Based on the prediction model, the 99 % individual prediction intervals (IPI) of VNA titres were established at 3, 6, 12 and 18 months for the 12 characteristic populations respectively. The cases of VNA below 0.5 IU/ml first appeared at 6 months in group D of primary vaccinations and at 10 years in group F of boosters. We conclude that for primary vaccination 2-1-1 schedule is more efficient than 5-dose; the use of residual rabies immunoglobulin for distal intramuscular injection isn't recommended. The 99 % IPI of VNA titres could provide the appropriate timing for booster vaccination.

Keywords: Rabies vaccination; Virus neutralizing antibody; Post-exposure prophylaxis; Influencing factors; Prediction model

25. **Rabies post-exposure prophylaxis in the emergency department: A monocentric retrospective observational study,** Mareen Braunstein, Markus Wörnle, **Travel Medicine and Infectious Disease**, Volume 61, 2024, 102750, https://doi.org/10.1016/j.tmaid.2024.102750.

Abstract

Background

Emergency departments (ED) are frequently visited after suspected rabies exposure (SRE) and the potential need for rabies post-exposure prophylaxis (R-PEP). However, data on the number of visits, patients' demographics, travel history and the medical treatment is still rare. Therefore, the aim of this study was to assess the number of R-PEP and the appropriateness of medical management including wound treatment, vaccination regime and immunoglobulin application following SRE in a university hospital ED.

Method

We conducted a monocentric retrospective observational study on emergency patients treated in the ED of the LMU University Hospital, Ludwig-Maximilians-University Munich, Germany, between June 1st, 2023 and January 31st, 2024. Patients requiring post-exposure prophylaxis due to SRE abroad or in Germany were included. Demographic data, travel history, clinical findings, wound treatment, and R-PEP vaccination regimen were recorded.

Results

During the observation period of 245 days 43 patients presented to our ED for R-PEP. There was a total of 51 presentation appointments, as 5 patients returned for further treatment. Most patients (27, 52.9 %) presented at the ED on a Saturday, Sunday, or a public holiday. 17 (39.5 %) patients had a category II exposure, and 26 (60.5 %) had a category III exposure. In our ED, there were 28 (55.0 %) active vaccinations and 23 (45.0 %) both active and passive vaccinations.

Conclusions

Our data show that patients frequently present for R-PEP in ED. Therefore, there is a high need for education on indication for R-PEP and for implementation of precise R-PEP treatment guidelines in daily clinical practice.

Keywords: Essen regimen; Rabies immunoglobulin; Travel medicine; Wound treatment; Zagreb regimen

26. **The NF-κB pathway negatively regulates the replication of rabies virus by triggering inflammatory responses,** Yujie Bai, Hongli Jin, Yongsai Liu, Pei Huang, Yuanyuan Li, Hualei Wang, Haili Zhang, Xianzhu Xia, **Animals and Zoonoses**, Volume 1, Issue 1, 2025, Pages 61-68, https://doi.org/10.1016/j.azn.2024.04.001.

Abstract

Rabies, which is caused by the rabies virus (RABV), is a neurological disease of mammals, including humans. The disease is untreatable, as drugs and antibodies are prevented from entering brain tissue by the blood-brain barrier (BBB). However, it has been reported that BBB permeability can be enhanced in mice infected with a laboratory-attenuated strain of RABV, which is not the case in those infected with wild-type RABV. Moreover, it is not the RABV infection directly that enhances BBB, but rather the inflammatory molecules that are induced by the virus. Understanding the mechanism underlying the RABV-induced production of chemokines and cytokines is crucial for the prevention and management of rabies. In this study, we found that mice infected with the RABV challenge strain CVS11 showed significant inflammatory infiltration in the later stages of infection. At the cellular level, we confirmed that the NF-κB signaling pathway was activated following RABV infection, leading to significant upregulation of the expression of downstream chemokines and inflammatory factors (CCL2, CCL5, CXCL10, TNF-α, and IL-6). Surprisingly, the replication of RABV was upregulated when the NF-κB pathway was inhibited, and the levels of its downstream chemokines and inflammatory factors were reduced following treatment with the inhibitor JSH-23. This suggests that RABV infection activates the NF-κB pathway, which is then able to negatively regulate the replication of RABV. This pathway is therefore a potential target for drugs and other therapies in the treatment of rabies.

Keywords: Rabies virus; Inflammatory responses; NF-κB pathway; Negative regulation

27. **Factors influencing canine rabies vaccination among dog-owning households in Nigeria,** Philip P. Mshelbwala, Charles E. Rupprecht, Modupe O. Osinubi, Emmanuel O. Njoga, TereseG.Orum, J.ScottWeese, NicholasJ.Clark, **One Health**, Volume18, 2024, 100751, https://doi.org/10.1016/j.onehlt.2024.100751.

Abstract

Rabies perpetuates in Nigeria despite initiatives like the Regional Disease Surveillance System Enhancement Project, with evidence indicating suboptimal canine vaccination rates as a contributing factor. To inform effective planning of mass dog vaccination campaigns, it is crucial to understand the factors associated with variation in canine vaccination rates. We conducted a cross-sectional study in 2022 to understand factors associated with canine vaccination. We used stratified random sampling of the streets and dog-owning households to survey 4162 households from three states and the Federal Capital Territory (FCT). We then built a joint probabilistic model to understand factors associated with dog vaccination and non-vaccination. First, we modelled rabies knowledge as a latent variable indirectly measured with several targeted survey questions. This method allowed a respondent's unobserved understanding of rabies to be estimated using their responses to a collection of survey questions that targeted different aspects of rabies epidemiology and took various possible response distributions (i.e., ordinal, categorical, binary). Second, we modelled factors influencing pet owners' decisions to vaccinate their dogs against rabies and barriers to dog vaccination among dog owners whose dogs were not vaccinated against rabies. Posterior distributions revealed that the probability of dog vaccination was positively associated with the owner's latent knowledge of rabies, civil servant service employment, residence in the FCT, ownership of a single dog, providing care to dogs, and a preference for contemporary treatment following a dog bite. Conversely, non-vaccination was positively associated with private employment, residing in Anambra and Enugu states, owning multiple dogs, allowing dogs to search for leftovers, and a preference for traditional treatment after a dog bite. Cost was the primary barrier against vaccination for dog owners in Anambra and Enugu, while mistrust posed a major challenge for those in the FCT. Owners in areas with veterinary establishments cited cost as a barrier, while those without a veterinary establishment cited access as the primary barrier. Our study underscores the need to enhance rabies knowledge, tailor vaccination campaigns to specific demographics, address financial and access barriers, and combat hesitancy to improve rabies vaccination rates in Nigeria.

Keywords: Nigeria; Rabies; Bayesian; Dog; Vaccination; Risk factors; Modelling

28. **Oral rabies vaccination of foxes in Türkiye, 2019–2022,** Orhan Aylan, Bayram Sertkaya, Anıl Demeli, Ad Vos, Sabri Hacioglu, Yeşim Tatan Atıcı, Deniz Acun Yıldız, Thomas Müller, Conrad M. Freuling, **One Health**, Volume 19, 2024, 100877, https://doi.org/10.1016/j.onehlt.2024.100877.

Abstract

Background

Rabies in Turkey is maintained by dogs, but following a sustained spill-over, red fox mediated rabies had spread from the Aegean region to the central part of Türkiye. During the past four years from 2019 to 2023 large scale efforts used oral rabies vaccination (ORV) to control rabies in red foxes. Here, we present the results of the largest ORV campaign on the Asian continent.

Methods

ORV campaigns were carried out twice a year in spring and autumn with a targeted bait density of 20–23 baits/km2. Monitoring of ORV campaigns included the GIS-based analyses of bait distribution, the assessment of bait uptake through biomarker detection and the determination of seroconversion (sero-positivity in ELISA) in the target species collected within the vaccination area. For determination of fox rabies incidence in vaccination areas as the main indicator of the performance of the ORV campaigns, epidemiological data was obtained from the national passive surveillance program.

Results

Aerial bait distribution was highly accurate, with >99 % of baits being recorded from targeted zones, thus meeting the desired bait densities. Although the overall bait uptake (28.1 %; 95 %CI: 23.2–32.8) and seroprevalance (36.3 %; 95 %CI: 30.0–43.2) were low, rabies incidence drastically decreased in ORV areas and rabies was eliminated from western and central parts of Turkey, with no reported cases in foxes from ORV areas in 2022 and 2023.

Conclusions

A large-scale ORV campaign against fox rabies using high quality vaccine baits and the GIS-aided and monitored bait distribution was able to control fox mediated rabies in the western and central parts of Türkiye. Rabies control both in dogs and foxes should be expanded to cover also the eastern parts of Türkiye, to become eventually rabies free.

Keywords: Rabies; Red fox; Türkiye; Oral vaccination; SAD-B19

29. **The epidemiology and clinical features of post-exposure prophylaxis for rabies: A retrospective study of 9772 cases,** Xin Jiang, Junlian Li, Jialing Pan, Lu Cheng, Cheng Jiang, Rui Wang, **One Health**, Volume 18, 2024, 100743, https://doi.org/10.1016/j.onehlt.2024.100743.

Abstract

Background

In December 2015, the World Health Organization, the World Animal Health Organization, and the Food and Agriculture Organization of the United Nations convened the International Congress on the elimination of rabies in Geneva. How to use epidemiological factors of post-exposure prophylaxis to prevent rabies has become the focus of attention.

Objective

To analyze the epidemiological characteristics of 9772 patients with rabies in a four-year period in one hospital, to clarify the outbreak law of rabies and to explore the corresponding prevention and control strategies.

Methods

The epidemiological data of rabies patients were collected from the infectious disease reporting information management system of the hospital from July 2018 to June 2022. The distributional characteristics of 13 influencing factors were analyzed using the chi-square test and linear regression.

Results

There was a significant correlation between the number of wounds and age, and the numbers of female and male patients were close. People over the age of 44 were more likely to get bites or scratches on their lower extremity ($P<0.0001$). There was a greater possibility for elderly people to be bitten by dogs ($P<0.0001$). Dogs preferred to bite or scratch lower limbs ($P<0.0001$), while cats upper limbs ($P<0.0001$). Upper limbs were more possibly attacked by animals at home ($P<0.0001$). There were significant correlations among exposure grade, wound treatment and number of wounds. Conclusions: Lower extremity protection is needed for the elderly and when encountering dogs, and more attention needs to be paid to the upper extremities when encountering cats and household pets, as well as pets that are cute but need to be protected from bites or scratches.

Keywords: Rabies; Prevention; Prevalence characteristics; Post-exposure prophylaxis

30. Rabies incidence and burden in three cities of Cameroon (2004–2013), Ngah Osoe Bouli Freddy Patrick, Awah-Ndukum Julius, Mingoas Kilekoung Jean-Pierre, Mouiche Mouliom Mohamed Moctar, **Veterinary and Animal Science**, Volume 24, 2024, 100347, https://doi.org/10.1016/j.vas.2024.100347.

Abstract

Rabies is a fatal disease occurring worldwide and especially in almost all the countries in Asia and Africa including Cameroon. Though animal and human rabies is prevalent in Cameroon, the epidemiology and socio-economic burden of the disease in the country is not known. Therefore, a 10-year (October 2004–April 2013) retrospective study on the incidence of animal and human rabies and its burden in Garoua, Ngaoundéré and Yaoundé in Cameroon was carried out. Records of human cases were extracted from the database of the regional hospitals, and animal cases from the databases of Centre Pasteur and National Veterinary Laboratory. The burden of the disease was assessed through the estimation of costs linked to preventive measures (vaccination), corrective procedures (Post Exposure Treatment), Disability-Adjusted Life Year (DALY) and overall societal cost of the disease. Overall, 56 rabies-suspected human deaths, corresponding to an incidence of 0.02 ± 0.00 ‰ and Animal Rabies Incidence (ARI) of 0.37 ± 0.00 % among 1844 suspected animal cases were recorded. The economic loss due to preventive measures of 326,046 ± 28,130.85 USD, related to corrective procedures of 806,741.25 ± 2,466.08 USD, and DALY of 1690.28 ± 4.76 years were estimated. This is the first study that highlights the enormous socio-economic burden associated with animal and human rabies in endemic parts of Cameroon and emphasizes on enhancing rabies eradication strategy focusing on the One Health approach.

Keywords: Rabies; Incidence; Dogs; Humans; Burden; DALY; Cameroon

31. **Adjuvant activity of cordycepin, a natural derivative of adenosine from Cordyceps militaris, on an inactivated rabies vaccine in an animal model,** Xin Chen, Boyu Liao, Tianci Ren, Zhipeng Liao, Zijie Huang, Yujuan Lin, Shouhao Zhong, Jiaying Li, Shun Wen, Yingyan Li, Xiaohan Lin, Xingchen Du, Yuhui Yang, Jiubiao Guo, Xiaohui Zhu, Haishu Lin, Rui Liu, Jingbo Wang, **Heliyon**, Volume 10, Issue 2, 2024, e24612, https://doi.org/10.1016/j.heliyon.2024.e24612.

Abstract

Vaccination is the most feasible way of preventing rabies, an ancient zoonosis that remains a major public health concern globally. However, administration of inactivated rabies vaccination without adjuvants is always inefficient and necessitates four to five injections. In the current study, we explored the adjuvant characteristics of cordycepin, a major bioactive component of Cordyceps militaris, to boost immune responses against a commercially available rabies vaccine. We found that cordycepin could stimulate stronger phenotypic and functional maturation of dendritic cells (DCs). For animal experiments, mice were immunized 3 times with rabies vaccine in the presence or absence of cordycepin at 1-week interval. Analysis of T cell differentiation and serum antibody isotypes showed that humoral immunity was dominant with a Th2 biased immune response. These results were also supported by the raised ratio of follicular helper T cells (TFH) and germinal center B cells (GCB). Thus, titer of rabies virus neutralizing antibody (RVNAb) and rabies virus-specific memory B cells were both raised as a result. Furthermore, administration of cordycepin did not cause pathological phenomena or body weight loss. The findings indicate that cordycepin could be used as a promising adjuvant for rabies vaccines to get a higher range of protection without any side effects.

Keywords: Rabies vaccine; Cordycepin; Adjuvant

32. **Rabies encephalitis following Post Exposure prophylaxis (PEP) is becoming an evolving problem in Bangladesh,** Shrebash Paul, Majeda Khanam, Md. Abdullah Saeed Khan, Sanzida Khan, Md. Zobaer Ahmed, Hashiba Moontaha, Bikash Kumar Sarkar, Sumaiya Binte Azad, Md. Touhidul Murshid, Tanzina Jahan, A.R.M. Sakhawat Hossain Khan, Sonja Leonhard, Ariful Basher, **The Microbe**, Volume 3, 2024, 100094, https://doi.org/10.1016/j.microb.2024.100094.

Abstract

Rabies is one of the oldest and deadliest disease in the world and causes a significant number of deaths. Over 95 % of all human deaths from rabies occur in Asia and Africa. Bangladesh is endemic to rabies. Since the National Rabies Elimination Program was successfully implemented in 2010, Bangladesh has achieved considerable strides in preventing human mortality from rabies. Rabies post-exposure prophylaxis (PEP) is widely used and very effective. However, occasional incidences of rabies in individuals who have initiated or completed PEP have been documented. In this observational cohort study, a total of 45 clinically diagnosed rabies patients, irrespective of age and gender, from 33 different districts of Bangladesh were studied. A detailed clinico-demographic profile, including post-exposure prophylaxis received before the development of rabies, was recorded. RT-PCR for rabies was done on the saliva samples of all patients. An MRI, EEG, and CSF viral panel was also done for patients who were RT-PCR negative. From January 2022 to June 2023, 45 clinically diagnosed rabies cases were admitted to IDH. Two of them were PCR-positive. The median age of the patients was 11 years (IQR 5–40 years). 37 (82.2 %) were males. Dogs were the most commonly accused animal (86.5 %). The median time from exposure to the development of rabies symptoms was 37 days (IQR 22–60 days, range 07–240 days). The median duration of illness was 5 days (IQR: 3–7 days). All of the patients had severe exposure. Only 5 (11 %) patients received complete WHO-recommended post-exposure prophylaxis (PEP). 20 (45 %) patients received only the rabies vaccine (incomplete PEP) without a wound wash or RIG. All the patients received supportive management. In addition to that, three patients were given intrathecal RIG at 40 U/kg/dose for two doses seven days apart. Out of three patients, two survived for more than two months. One patient is still alive after six months with significant morbidity. There is no cure for rabies; however, appropriate animal bite management by trained medical personnel with WHO-recommended PEP is the only way to achieve the goal of a rabies-free world.

Keywords: Rabies encephalitis; Animal bite; Rabies immunoglobulin; IDH; Bangladesh

33. **Routine childhood rabies pre-exposure prophylaxis can be cost effective in low- and middle-income countries,** Adam John Ritchie, Aronrag Meeyai, Caroline Trotter, Alexander D. Douglas, **Vaccine**, Volume 47, 2025, 126703, https://doi.org/10.1016/j.vaccine.2024.126703.

Abstract

Background

Pre-exposure prophylactic rabies vaccination (PrEP) is advised for travellers to countries with high rabies incidence, but rarely available for local residents. Some studies suggest poor cost-effectiveness of PrEP in such settings, but have generally focused upon post-exposure prophylaxis (PEP) cost savings as the main benefit of PrEP, without considering lives saved by PrEP efficacy.

Methods

We compared incremental cost-effectiveness ratios (ICERs) of use of rabies PrEP, against an alternative of using only PEP, by adapting a decision-tree model previously used to inform Gavi's investment in rabies PEP. We consider scenarios including: a range of PrEP efficacies in individuals unable to access PEP; PrEP costs significantly below current prices (through single-dose approaches, inclusion in childhood vaccination schedules, increased manufacturing volume and/or new low-cost products); and variable rabies exposure risk and PEP access. We also present results from a simplified model, designed for ease of understanding.

Results

Modelled ICERs were <1000 USD per quality adjusted life year (QALY) across a range of plausible combinations of rabies exposure risk, PEP access, PrEP cost and PrEP efficacy. If PrEP efficacy exceeds 50 % over 15 years, we estimate ICERs <500 USD/QALY where rabies incidence ≥3 per 100,000 per year and cost of vaccination is ≤5 USD/child. Under scenarios with lower rabies incidence of around 0.3 per 100,000 per year, due either to more limited exposure or greater access to PEP, ICERs <3000 USD may still be achieved even if PrEP efficacy is as low as 30 %.

Conclusions

Routine childhood PrEP may be cost-effective in settings with modest willingness-to-pay, and rabies exposure risks plausible across much of Africa and South Asia. Cost-effectiveness requires low-cost PrEP regimes and some efficacy of PrEP in individuals unable to access PEP. Under such conditions, PrEP may be an attractive additional tool in the fight against rabies.

Keywords: Rabies; Vaccination; Pre-exposure prophylaxis (PrEP); Cost-effectiveness; Modelling

34. **Communication channel preference for raising rabies awareness among dog owners in Thailand: A nationwide study,** Wagee Worrawattanatam, Wongsaton Ektasaeng, Phakwat Pornsuksant, Sarin Suwanpakdee, Sith Premashthira, Anuwat Wiratsudakul, **One Health**, Volume 20, 2025, 100955, https://doi.org/10.1016/j.onehlt.2024.100955.

Abstract

Rabies is a severe zoonotic disease with potentially fatal consequences. Effective communication channels are crucial for disseminating key rabies prevention and control messages to target populations. This study examined how dog owners' demographic factors influenced communication channels in Thailand. We distributed a questionnaire survey to retrieve general demographic data of participants and the ranks of their communication channels. We used the mean ranking score to assess the most accessible and commonly used platforms. Univariate and multiple logistic regression methods were used to determine the association between each demographic feature and the preference for communication. In total, 476 participants were involved across all regions of Thailand. Village health volunteers represented the most selected channel, as identified by the mean ranking (3.32), followed by public loudspeaker (3.30) and television (2.93). Age, occupation, region, and cat ownership significantly influenced how people chose the channels. Moreover, farmers likely received information from various sources, and elderly individuals generally preferred to receive information about rabies from administrative authorities, such as village heads. These results can benefit policymakers aiming to enhance communication strategies in public health. This study enhances rabies risk communication and aligns with global health initiatives to eliminate dog-mediated rabies by 2030.

Keywords: Epidemiology; Health literacy; Risk communication; Zoonosis

35. **Understanding the journey towards rabies vaccination for travellers: Results of a cross-sectional survey with patients and providers in the US, Germany, Sweden, and Switzerland,** Jennifer Cummins, Florian Lienert, Annabel Su, Elaine Melander, Rebecca L. West, Fernanda Salgado, **Travel Medicine and Infectious Disease**, Volume 62, 2024, 102767, https://doi.org/10.1016/j.tmaid.2024.102767.

Abstract

Background

Although cases of rabies in international travellers are uncommon, they are a fatal risk which can be alleviated through vaccination prior to travel. As international travel recovers post-COVID, it is vital that travellers are made aware of the risk of rabies when travelling to endemic countries and supported to receive the vaccine when eligible.

Methods

Online surveys were conducted in the US, Germany, Sweden and Switzerland between November 2022–January 2023 with both patients and healthcare providers (HCPs). Eligibility criteria for patients included those eligible for rabies pre-exposure prophylaxis (PrEP) due to travel location and activity; HCPs had to be providers of travel vaccinations. In both surveys, questions were asked about discussion of rabies vaccination, decision of whether to administer a rabies vaccine, recommendation to get the rabies vaccine, and final decision to get a vaccine.

Results

The final patient sample included n = 1557 patients who were eligible for rabies pre-exposure prophylaxis (US n = 504, Germany n = 353, Sweden n = 350, Switzerland n = 350) and n = 219 HCPs (US n = 75, Germany n = 75, Sweden n = 32, Switzerland n = 37). Although all patients in the sample were eligible for rabies vaccination, only 15 % felt they were at risk of getting rabies, and only 18 % received the rabies vaccine before their trip. HCPs reported discussing PrEP and/or PrEP and PEP with 30 % of patients presenting for travel vaccination advice, on average.

Conclusions

Awareness and perception of rabies risk, and lack of consistent HCP discussion of the need for rabies PrEP may be major barriers to uptake of the vaccine for patients who are eligible to receive it.

Keywords: Rabies; Pre-exposure prophylaxis; Travel medicine; Vaccination

36. **Rabies control in Bangladesh and prediction of human rabies cases by 2030: a One Health approach,** Sumon Ghosh, Mohammad Nayeem Hasan, Nirmalendu Deb Nath, Najmul Haider, Daleniece Higgins Jones, Md. Kamrul Islam, M. Mujibur Rahaman, Hasan Sayedul Mursalin, Nadim Mahmud, Md. Kamruzzaman, Md. Fazlay Rabby, Shotabdi Kar, Sayed Mohammed Ullah, Md. Rashed Ali Shah, Afsana Akter Jahan, Md. Sohel Rana, Sukanta Chowdhury, Md. Jamal Uddin, Thankam S. Sunil, Be-Nazir Ahmed, Umme Ruman Siddiqui, S.M. Golam Kaisar, Md. Nazmul Islam, **The Lancet Regional Health - Southeast Asia**, Volume 27, 2024, 100452, https://doi.org/10.1016/j.lansea.2024.100452.

Abstract

Background

Bangladesh is making progress toward achieving zero dog-mediated rabies deaths by 2030, a global goal set in 2015.

Methods

Drawing from multiple datasets, including patient immunisation record books and mass dog vaccination (MDV) databases, we conducted a comprehensive analysis between 2011 and 2023 to understand the effectiveness of rabies control programmes and predict human rabies cases in Bangladesh by 2030 using time-series forecasting models. We also compared rabies virus sequences from GenBank in Bangladesh and other South Asian countries.

Findings

The estimated dog population in Bangladesh was determined to be 1,668,140, with an average dog population density of 12.83 dogs/km2 (95% CI 11.14–14.53) and a human-to-dog ratio of 86.70 (95% CI 76.60–96.80). The MDV campaign has led to the vaccination of an average of 21,295 dogs (95% CI 18,654–23,935) per district annually out of an estimated 26,065 dogs (95% CI 22,898–29,230). A declining trend in predicted and observed human rabies cases has been identified, suggesting that Bangladesh is poised to make substantial progress towards achieving the 'Zero by 30' goal, provided the current trajectory continues. The phylogenetic analysis shows that rabies viruses in Bangladesh belong to the Arctic-like-1 group, which differs from those in Bhutan despite sharing a common ancestor.

Interpretation

Bangladesh's One Health approach demonstrated that an increase in MDV and anti-rabies vaccine (ARV) resulted in a decline in the relative risk of human rabies cases, indicating that eliminating dog-mediated human rabies could be achievable.

Funding

The study was supported by the Communicable Disease Control (CDC) Division of the Directorate General of Health Services (DGHS) of the People's Republic of Bangladesh.

Keywords: Human rabies; Time-series forecasting models; Mass dog vaccination; Bangladesh

37. **Identification of clade-defining single nucleotide polymorphisms for improved rabies virus surveillance,** Ankeet Kumar, Sheetal Tushir, Yashas Devasurmutt, Sujith S. Nath, Utpal Tatu, **New Microbes and New Infections**, Volume 62, 2024, 101511, https://doi.org/10.1016/j.nmni.2024.101511.

Abstract

Background

Rabies is an ancient disease that remains endemic in many countries. It causes many human deaths annually, predominantly in resource-poor countries. Over evolutionary timelines, several rabies virus (RABV) genotypes have stabilised, forming distinct clades. Extensive studies have been conducted on the origin, occurrence and spread of RABV clades. Single nucleotide polymorphisms (SNPs) distribution across the RABV genome and its clades remains largely unknown, highlighting the need for comprehensive whole-genome analyses.

Methods

We accessed whole genome sequences for RABV from public databases and identified SNPs across the whole genome sequences. Then, we annotated these SNPs using an R script, and these SNPs were categorised into different categories; universal, clade-specific, and clade-defining, based on the frequency of occurrence.

Results

In this study, we present the SNPs occurring in the RABV based on whole genome sequences belonging to 8 clades isolated from 7 different host species likely to harbour dog-related rabies. We classified mutations into several classes based on their location within the genome and assessed the effect of SNP mutations on the viral glycoprotein.

Conclusions

The clade-defining mutations have implications for targeted surveillance and classification of clades. Additionally, we investigated the effects of these mutations on the Glycoprotein of the virus. Our findings contribute to expanding knowledge about RABV clade diversity and evolution, which has significant implications for effectively tracking and combatting RABV transmission.

Keywords: Rabies virus (RABV); Single nucleotide polymorphisms (SNP) analysis; Whole genome SNP analysis; Canine rabies; Mutations in RABV clades

38. **Computational structure-based design of antiviral peptides as potential protein–protein interaction inhibitors of rabies virus phosphoprotein and human LC8,** Saman Rahmati, Fatemeh Zandi, Khadijeh Ahmadi, Ahmad Adeli, Niloofar Rastegarpanah, Massoud Amanlou, Behrouz Vaziri, **Heliyon**, Volume 11, Issue 1, 2025, e41520, https://doi.org/10.1016/j.heliyon.2024.e41520.

Abstract

Rabies is a serious zoonotic disease caused by the rabies virus (RABV). Despite the successful development of vaccines and efforts made in drug discovery, rabies is incurable. Therefore, development of novel drugs is of interest to the scientific community. Antiviral peptides can be designed based on the known structures of viral proteins and their biological targets. Cytoplasmic dynein light chain LC8, one of the first identified host partners of RABV phosphoprotein (RABV P), is an essential factor for RABV transcription and replication. As part of the search for new potential drugs against rabies, we used structure-based drug design using the in silico tools. The binding site of LC8 with RABV P was used for peptide design. Four potential peptide inhibitors (Pep1-4) were selected, modeled, and docked with RABV P. The highest binding affinity was observed for the RABV P-Pep2 complex. Molecular dynamics (MD) simulations were performed and the stability of the peptides and complexes was confirmed. Finally, Pep2 can be used as a potential candidate for peptide-based antiviral therapy against RABV. The identified small peptides may prevent RABV infection based on the results of the current investigation. Further in vitro and in vivo studies are needed to confirm these results.

Keywords: RABV phosphoprotein; LC8; Antiviral peptides; Docking; Molecular dynamics simulation

39. **Structural insight into rabies virus neutralization revealed by an engineered antibody scaffold,** Ashwini Kedari, Rommel Iheozor-Ejiofor, Petja Salminen, Hasan Uğurlu, Anna R. Mäkelä, Lev Levanov, Olli Vapalahti, Vesa P. Hytönen, Kalle Saksela, Ilona Rissanen, **Structure**, Volume 32, Issue 12, 2024, Pages 2220-2230.e4, https://doi.org/10.1016/j.str.2024.10.002.

Abstract

Summary

Host-cell entry of the highly pathogenic rabies virus (RABV) is mediated by glycoprotein (G) spikes, which also comprise the primary target for the humoral immune response. RABV glycoprotein (RABV-G) displays several antigenic sites that are targeted by neutralizing monoclonal antibodies (mAbs). In this study, we determined the epitope of a potently neutralizing human mAb, CR57, which we engineered into a diabody format to facilitate crystallization. We report the crystal structure of the CR57 diabody alone at 2.38 Å resolution, and in complex with RABV-G domain III at 2.70 Å resolution. The CR57−RABV-G structure reveals critical interactions at the antigen interface, which target the conserved “KLCGVL” peptide and residues proximal to it on RABV-G. Structural analysis combined with a cell-cell fusion assay demonstrates that CR57 effectively inhibits RABV-G-mediated fusion by obstructing the fusogenic transitions of the spike protein. Altogether, this investigation provides a structural perspective on RABV inhibition by a potently neutralizing human antibody.

Keywords: rabies virus; rabies glycoprotein; mAb CR57; diabody; antibody engineering; antibody-mediated neutralization; X-ray crystallography; fusion inhibition

40. **Evaluation of contingency actions to control the spread of raccoon rabies in Ohio and Virginia,** Amy J. Davis, Richard B. Chipman, Kathleen M. Nelson, Betsy S. Haley, Jordona D. Kirby, Xiaoyue Ma, Ryan M. Wallace, Amy T. Gilbert, **Preventive Veterinary Medicine**, Volume 225, 2024, 106145, https://doi.org/10.1016/j.prevetmed.2024.106145.

Abstract

The raccoon (Procyon lotor) variant of the rabies virus (RRV) is enzootic in the eastern United States and oral rabies vaccination (ORV) is the primary strategy to prevent and control landscape spread. Breaches of ORV management zones occasionally occur, and emergency "contingency" actions may be implemented to enhance local control. Contingency actions are an integral part of landscape-scale wildlife rabies management but can be very costly and routinely involve enhanced rabies surveillance (ERS) around the index case. We investigated two contingency actions in Ohio (2017–2019 and 2018–2021) and one in Virginia (2017–2019) using a dynamic, multi-method occupancy approach to examine relationships between specific management actions and RRV occurrence, including whether ERS was sufficient around the index case. The RRV occupancy was assessed seasonally at 100-km2 grids and we examined relationships across three spatial scales (regional management zone, RRV free regions, and local contingency areas). The location of a grid relative to the ORV management zone was the strongest predictor of RRV occupancy at the regional scale. In RRV free regions, the neighbor effect and temporal variability were most important in influencing RRV occupancy. Parenteral (hand) vaccination of raccoons was important across all three contingency action areas, but more influential in the Ohio contingency action areas where more raccoons were hand vaccinated. In the Virginia contingency action area, ORV strategies were as important in reducing RRV occupancy as a hand vaccination strategy. The management action to trap, euthanize, and test (TET) raccoons was an important method to increase ERS, yet the impacts of TET on RRV occupancy are not clear. The probability of detecting additional cases of RRV was exceptionally high (>0.95) during the season the index case occurred. The probability of detecting RRV through ERS declined in the seasons following initial TET efforts but remained higher after the contingency action compared to the ERS detection probabilities prior to index case incidence. Local RRV cases were contained within one year and eliminated within 2–3 years of each contingency action.

Keywords: Contingency action; Dynamic occupancy; Multi-method approach; Oral rabies vaccination; Outbreak control; Procyon lotor; Rabies virus; Wildlife disease management

41. Spatiotemporal dynamics of rabies virus detected in rabid dogs in Cameroon, 2010–2021, Jocelyne Noel Sowe Wobessi, Jean-Luc Bailly, Jean-Marc Kameni Feussom, Richard Njouom, Serge Alain Sadeuh-Mba, **Infection, Genetics and Evolution**, Volume 126, 2024, 105688, https://doi.org/10.1016/j.meegid.2024.105688.

Abstract

Rabies is a viral zoonosis that causes an estimated 60,000 human deaths each year, mainly in Africa and Asia. The etiological agent of rabies, the Rabies Lyssavirus or Rabies Virus (RABV) has been characterized in dog populations in Cameroon, in previous studies. However, the dynamics of RABV maintenance and propagation in dogs are still to be documented in Cameroon. This study thus, aimed at investigating the spatial and temporal dynamics of RABV variants in Cameroon. Long genomic sequences of about 4893 nucleotides, encompassing the N, P, M and G genes as well as part of the G-L intergenic region (Ψ), were determined from 56 RABV strains recovered from dog populations in Cameroon from 2010 to 2021. Temporal and spatial dynamics of RABV circulation in Cameroon were investigated by Bayesian analyses with the BEAST 1.10.4 package from extended RABV genomic sequences data combined with their collection dates and the geographical coordinates of their sampling areas. This revealed a genetic evolution rate of 3.14 × 10−4 substitutions/site/year among Africa-1a and Africa-2 clades of RABV from Cameroon. The most recent common ancestor (MRCA) of the studied strains of the Africa-1a lineage was estimated to have emerged between 1880 and 1906 (95 % HPD; mean 1894), while that of the strains of the Africa-2 clade had a slightly later estimated origin between 1907 and 1928 (95 % HPD, mean 1918). Overall, phylogeographic analyses suggested RABV spread in Cameroon between sub-national regions. Our data provides substantial support to previous findings from similar epidemiological settings, indicating human mediated movements of infected dogs between distant cities may be a key factor in the maintenance of the enzootic cycle of rabies among dogs in Cameroon.

Keywords: Rabies; Dog; Phylodynamics; Phylogeography; Cameroon

42. **Rabies in rural northeast India: A case report emphasising the urgency of the One Health approach,** Parimala Mohanty, Prasanta Kumar Boro, Samira Heydtmann, Salome Durr, Harish Kumar Tiwari, **One Health**, Volume 19, 2024, 100850, https://doi.org/10.1016/j.onehlt.2024.100850.

Abstract

Dog-mediated rabies is endemic in India. The country records the highest mortality due to dog-bite-related rabies despite the availability of interventions to prevent deaths. We present a case study of the death of a 59-year-old man in a suburban town of Northeast India after a dog bite from an owned pup. Through this case study, we investigate various omissions and commissions in communities and health professionals that make rabies rampant in India. The circumstances surrounding the death were investigated by interviewing the wife, relatives, neighbour, the hospital/nursing home where the bite case was reported, the district Rapid Response Team (RRT), and the Veterinary and Animal Health Department Officer and through the information recorded in the disease outbreak report. While the biting animal was not vaccinated and had no restriction over its movement imposed by the owners, the response of the hospital staff and public authorities was delayed and inadequate. A poignant reminder of the complexities surrounding dog-mediated rabies in India, this case study calls for a holistic protocol to address dog bites through ensuring the One Health approach encompassing education, provision of post-exposure prophylaxis (PEP) and canine rabies vaccines for dogs, promotion of responsible dog ownership, and intersectoral collaboration. Moreover, strengthening communication channels through effective data exchange and encouraging synergy among healthcare, veterinary, and public health sectors is indispensable to maximize the impact of rabies prevention and control interventions.

Keywords: Rabies; Dog bite; Post-exposure prophylaxis; Healthcare infrastructure; Rabies death; Case report

43. **Assessment of the burden of rabies in one health approach control program in Ketapang District Indonesia: Using zDALY,** Cut Desna Aptriana, Etih Sudarnika, Chaerul Basri, Dikky Indrawan, Joko Daryono, Pebi Purwo Suseno, **Preventive Medicine Reports**, Volume 45, 2024, 102838, https://doi.org/10.1016/j.pmedr.2024.102838.

Abstract

Background

Ketapang District, located in West Kalimantan, is a region where rabies is endemic. The first human death from rabies was reported in 2014 and the problem persists to this day. In response, the government has implemented the one health approach to control rabies since 2017. This study aimed to assess the disease burden of rabies control using zDALY metrics.

Methods

The zoonotic burden for human and animal was measured by developing Zoonotic Disability-Adjusted Life Years (zDALY), which combines DALY and local values of animals and their products, considering animal morbidity and mortality due to the disease (Animal Loss Equivalent/ALE). Data were gathered through interviews with victims or their families, dog owners, and secondary data from the Animal Husbandry Service, and the District Health Office.

Results

Before implementing the one health approach, the zDALY value was 1,561.22 person-years (the zDALY rate: 109.53 years/100,000 people). After the intervention, the zDALY value was 1,808.86 person-years (the zDALY rate: 86.62 years/100,000 people).

Conclusions

This reduction in the zDaly rate indicates that rabies control through the one health approach in Ketapang District was effective in alleviating the disease burden caused by rabies.

Keywords: Animal loss equivalent; DALY; Disease burden; One health; Rabies; zDALY; Zoonoses

44. **Evaluation of safety and immunogenicity of a genetically modified rabies virus for use as an oral vaccine in several non-target species1,** Xijun Wang, Hong Huo, Lei Shuai, Jinying Ge, Liyan Peng, Jinming Wang, Shuang Xiao, Weiye Chen, Zhiyuan Wen, Jinliang Wang, Zhigao Bu, **Journal of Integrative Agriculture**, 2024, https://doi.org/10.1016/j.jia.2024.07.031.

Abstract

Oral immunization is an alternative or supplementary approach that can significantly improve dog vaccination coverage, especially for free-roaming dogs. Safe and effective oral rabies vaccines for dogs are still being sought. In our previous studies, we generated a genetically modified rabies virus (RABV) ERA strain, rERAG333E, containing a mutation from arginine (Arg, R) to glutamic acid (Glu, E) at residue 333 of the G protein (G333E). Our previous results demonstrated that rERAG333E was safe for adult mice and dogs, and oral vaccination with rERAG333E induced a strong and long-lasting protective immune response in dogs. Here, we further investigated the safety and immunogenicity of rERAG333E in non-target species, including suckling mice, rhesus monkeys, foxes, raccoon dogs, piglets, goats, and sheep. Suckling mice studies demonstrated that the G333E mutation significantly reduced the virulence of the ERA strain. All of the suckling mice aged 10 days and above survived and showed no apparent signs of disease after intracerebral inoculation with rERAG333E. Animal studies demonstrated that rERAG333E was safe in rhesus monkeys, foxes, raccoon dogs, piglets, goats, and sheep. None of those animals inoculated orally with 10 times the intended field dose of rERAG333E showed abnormal clinical signs before and after the booster immunization with Rabvac 3, an inactivated rabies vaccine. Meanwhile, oral inoculation with rERAG333E induced strong neutralizing antibody (NA) responses to RABV in rhesus monkeys, foxes, raccoon dogs, and piglets. These results demonstrated that rERAG333E has the potential to serve as a safe oral rabies vaccine for dogs.

Keywords: Rabies; Genetically modified rabies virus; Oral vaccine

45. **Mathematical model to assess the impact of contact rate and environment factor on transmission dynamics of rabies in humans and dogs,** Mfano Charles, Verdiana G. Masanja, Delfim F.M. Torres, Sayoki G. Mfinanga, G.A. Lyakurwa, **Heliyon**, Volume 10, Issue 11, 2024, e32012, https://doi.org/10.1016/j.heliyon.2024.e32012.

Abstract

This paper presents a mathematical model to understand how rabies spreads among humans, free-range, and domestic dogs. By analyzing the model, we discovered that there are equilibrium points representing both disease-free and endemic states. We calculated the basic reproduction number, R0 using the next generation matrix method. When R0<1, the disease-free equilibrium is globally stable, whereas when R0≥1, the endemic equilibrium is globally stable. To identify the most influential parameters in disease transmission, we used the normalized forward sensitivity index. The simulations revealed that the contact rates between the infectious agent and humans, free-range dogs, and domestic dogs, have the most significant impact on rabies transmission. The study also examines how periodic changes in transmission rates affect the disease dynamics, emphasizing the importance of transmission frequency and amplitude on the patterns observed in rabies spread. To reduce disease sensitivity, one should prioritize effective disease control measures that focus on keeping both free-range and domestic dogs indoors. This is a crucial factor in preventing the spread of disease and should be implemented as a primary disease control measure.

Keywords: Rabies disease; Mathematical model; Environment; Contact rate; Periodic transmission

46. **An optimised rabies vaccination schedule for rural settlements,** Rian Botes, Inger Fabris-Rotelli, Kabelo Mahloromela, Ding-Geng Chen, **Spatial Statistics**, Volume 65, 2025, 100877, https://doi.org/10.1016/j.spasta.2024.100877.

Abstract

The timely and efficient administration of rabies vaccinations to animals in rural villages is necessary to attain a state of herd immunity. Efficient sampling of households in a rural village is of utmost importance in reaching the most animals for vaccination, with the least effort, and in the lowest time. This research seeks to both optimise the spatial sampling scheme used to sample households, as well as the route travelled by persons performing door-to-door vaccinations. The walking time in minutes is regarded as the cost of a vaccination scheme and is minimised in this paper. The distribution of houses in a rural village constitutes a spatial point pattern in R2, and as such, spatial point pattern analysis techniques as well as some spatial sampling schemes are applied throughout this research. The penultimate aim of this work is to provide policy makers with additional tools to combat rabies, a disease which remains endemic to some countries in West and Central Africa, and Asia.

Keywords: Rabies; Sampling; Spatial sampling; Point patterns; Vaccination; Rural settlement; Kernel-weighted spatial sampling

47. **How a private organization in Pakistan initiated One Health Project to eliminate rabies,** Naseem Salahuddin, M. Aftab Gohar, Naila Baig-Ansari, Rabia Khan, M. Abdullah Qureshi, Kausar SK, Rashna Spencer Karanjia, Sara Salman, Isma Gheewala, **IJID One Health**, Volume 1, 2023, 100011, https://doi.org/10.1016/j.ijidoh.2023.100011.

Abstract

Objectives

In response to the escalating dog-bite incidents in Pakistan, the Indus Hospital Research Center (IHRC) introduced a pilot program of One Health to raise awareness about dog-related rabies in a fishing village in Karachi, and to vaccinate and sterilize unowned dogs in the area. The program was named “Rabies Free Pakistan” (RFP).

Design

Through community engagement, and financial and logistical support from multiple sources, field workers were trained to catch, vaccinate, neuter/spay, and release the dogs.

Results

The local community became aware of rabies and postexposure prophylaxis, while the team vaccinated 36,997dogs and sterilized 11,397 between 2018 and 2022. The outcome of a reduced dog population cannot be predicted for several years; however, cases of dog-bite outbreaks in the field reduced considerably, and the local people reported fewer puppies in 2022.

Conclusions

Despite many challenges, RFP proved to the community, the local government, and the donors that mass dog vaccination and neutering/spaying are possible through a collaborative effort. Political will is the primary requisite to carry on the One Health Initiative if rabies is to be eliminated from the country.

Keywords: One Health; Mass dog vaccination; Dog population control; Proof of concept; Rabies awareness

48. **Potential option for rabies post-exposure prophylaxis: New vaccine with PIKA adjuvant against diverse Chinese rabies strains,** Pengcheng Yu, Yuan Liu, Xiaoyan Tao, Ying He, Qian Liu, Bin Wang, Huiyu Zheng, Nan Zhang, Shengli Bi, Wuyang Zhu, Yi Zhang, **Vaccine**, Volume 41, Issue 46, 2023, Pages 6852-6862, https://doi.org/10.1016/j.vaccine.2023.10.001.

Abstract

Rabies is a fatal zoonotic disease caused by the rabies virus. Despite existing vaccines, failures still persist. Complete protection relies on improving vaccination for delayed antibody response and weak cellular immunity. A more effective and secure vaccine is necessary for rabies prevention. For this purpose, we employed the use of PIKA adjuvant, a stabilized double-stranded RNA that interacts with TLR3, as an enhancer for the rabies immunization. Testing on mice infected with seven rabies strains prevalent in China showed over 80% protective efficacy without immunoglobulin. In contrast, the PIKA rabies vaccine exhibited a more significant enhancement in neutralizing antibody levels just 5 days post-vaccination, surpassing the immune response induced by licensed rabies vaccines. Furthermore, the administration of the PIKA rabies vaccine resulted in a significant augmentation in the population of T cells that produce IFN-γ in response to the antigen. Additionally, elevated levels of IL-1β, IL-6, CCL-2, and TNF-α were observed at the injection site. Furthermore, an increase in the levels of chemotactic proteins and pro-inflammatory molecules in the serum was observed following administration of the PIKA rabies vaccine. Confirmation of the mechanism of action of PIKA was further established by testing it on TLR3-knockout mice, proving that its adjuvant function is dependent on the TLR3 pathway. Taken together, these results indicate that the PIKA vaccine for rabies shows potential as a highly efficacious approach, resulting in a significant enhancement of the efficacy of rabies vaccines.

Keywords: Rabies vaccine; PIKA adjuvant; Efficacy; Rabies virus variants; Post-exposure prophylaxis

49. **Rabies control in high-burden countries: role of universal pre-exposure immunization,** Lonika Lodha, Ashwini Manoor Ananda, Reeta S. Mani, **The Lancet Regional Health - Southeast Asia**, Volume 19, 2023, 100258, https://doi.org/10.1016/j.lansea.2023.100258.

Abstract

Summary

Rabies is a fatal zoonotic encephalitis that is responsible for approximately 59,000 deaths worldwide every year. A significant portion of these deaths, about one-third, occur in India alone. In order to meet the World Health Organization's objective of eliminating dog-mediated rabies by 2030, India has made considerable progress in this regard. However, implementing the current strategies of canine immunization, sterilization, and providing post-exposure prophylaxis to exposed individuals is challenging in a large and diverse country like India. This article aims to highlight the limitations of relying solely on post-exposure prophylaxis for the prevention of human rabies. Moreover, it presents the necessity and rationale for including pre-exposure immunization in India's national immunization schedule.

Keywords: Rabies; Immunization; Zoonosis

50. Impact of spatial and temporal resource distribution on rabies dynamics in the Arctic, Agathe Allibert, Francois Viard, Caroline C. Sauvé, Audrey Simon, Erin E. Rees, Patrick A. Leighton, **Arctic Science**, Volume 10, Issue 2, 2024, Pages 395-408, https://doi.org/10.1139/as-2023-0024.

Abstract

In the Arctic, rabies is endemic in the Arctic fox (Vulpes lagopus), posing a significant and ongoing health risk for people and domestic animals. The mechanisms by which rabies is maintained within the low-density fox populations in the Arctic remain unclear. In this study, we developed a spatially explicit individual-based stochastic epidemiological model and performed an uncertainty analysis to better understand Arctic fox rabies dynamics. Rabies persisted in 25.68% of model simulations, with several variables having significant impact on rabies persistence: probability of rabies transmission, spatial and temporal distribution food resources, mean litter size and variability of rabies incubation periods. Where rabies is endemic, we identified 5 key parameters for rabies dynamics: spatiotemporal resource distribution, probability of birth for adult females, mean and standard deviation of litter size, and incubation period of rabies. Our study demonstrates that Arctic rabies can persist in its primary host under conditions consistent with existing empirical data in the literature and showed the important role played by the spatial and temporal distribution of resources. Finally, our results suggest that the ecological impacts of rapid climate warming could decrease the overall persistence of rabies in the Arctic and the associated health risk in Arctic communities.

Keywords: Vulpes lagopus; public health; epidemiology; spatially explicit individualbased model; resources availability