



Factors Related to Immunity after Rabies Vaccination in the Dog Population Raised in An Giang Province, Viet Nam

NGUYEN PHI BANG^{1,2*}, NGUYEN THI HANH CHI^{1,2}, NGO THUY BAO TRAN^{1,2}, NGUYEN THI BICH HANH^{1,2}, NGUYEN BA TRUNG^{1,2}, LE THI THUY HANG^{1,2}

¹An Giang University, An Giang, Vietnam. No. 18. Ung Van Khiem Street, Dong Xuyen Ward, Long Xuyen City, An Giang Province; ²Vietnam National University Ho Chi Minh City, Vietnam.

Abstract | The rabies vaccine has been a crucial tool in controlling this hazardous disease globally. Its effectiveness is influenced by various factors, including the vaccine's quality, the animals' health, and the vaccination method. In An Giang (Vietnam), state veterinary officials use the Rabisin vaccine, which prevents rabies in pets when given to healthy canines by manufacturer's recommendations (stored at 2–8°C, 1 ml subcutaneous injection each dosage). Storage conditions and vaccine administration are carefully monitored to maintain consistent vaccine quality. However, factors related to dogs' health in this area have significantly affected the vaccination's effectiveness. This study was conducted to determine the factors affecting the efficacy of the Rabisin vaccine in preventing rabies in dogs in An Giang province (Vietnam). The study surveyed 343 vaccinated dogs of different ages to determine the presence of antibodies in the serum and compare factors related to the dogs' natural characteristics (age, gender) and other factors, such as dog management, regional characteristics, and vaccination timing. The study assessed the effectiveness of rabies vaccination in dogs by analyzing data from owners, health records, and serum samples. ELISA tests measured antibody levels, and statistical analysis, including chi-square and t-tests, was used to compare proportions and means, revealing that 80.47% of dogs developed protective antibodies. The highest antibody levels were in dogs aged >12–24 (89.47%, 7.44±0.49 EU/mL, 95% CI) months and >24–60 months (87.62%, 6.93±0.32 EU/mL, 95% CI), with significant ($P<0.05$) indicating solid associations. Confined or semi-confined dogs and those vaccinated within the last nine months (89.51%; 6.92±0.33 EU/mL, 95% CI) showed significantly better outcomes ($P=0.016$, $P=0.029$, 95% CI) compared to free-ranging dogs (73.68%, 5.13±0.35 EU/mL, 95% CI) and those vaccinated earlier (73.27%; 5.09±0.26 EU/mL, $P<0.05$). The study controlled for confounding factors like age, dog management method, and vaccination timing by statistically assessing their impact, underscoring the importance of proper dog management and timely booster vaccinations to optimize rabies prevention. These findings have significant implications for rabies prevention and control in An Giang province, Vietnam, and can guide future vaccination strategies and policies.

Keywords | Rabies, Immune response, Antibody titers, Dogs, Vaccination, An giang

Received | August 07, 2024; **Accepted** | October 05, 2024; **Published** | November 01, 2024

***Correspondence** | Nguyen Phi Bang, An Giang University, An Giang, Vietnam. No. 18. Ung Van Khiem Street, Dong Xuyen Ward, Long Xuyen City, An Giang Province; **Email:** npbang@agu.edu.vn

Citation | Bang NP, Chi NTH, Tran NTB, Hanh NTB, Trung NB, Hang LTT (2024). Factors related to immunity after rabies vaccination in the dog population raised in An Giang province, Viet nam. Adv. Anim. Vet. Sci. 12(12): 2549–2556.

DOI | <https://dx.doi.org/10.17582/journal.aavs/2024/12.12.2549.2556>

ISSN (Online) | 2307-8316; **ISSN (Print)** | 2309-3331



Copyright: 2024 by the authors. Licensee ResearchersLinks Ltd, England, UK.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Rabies, a disease that has been known to occur in underprivileged communities for over 4,000 years, is a global concern affecting both rural and urban areas. Dog bites cause 96% of human rabies cases, but attacks from cats, civets, jackals, leopards, wolves, and other predators have also been reported to cause human rabies (WHO, 2018). Once clinical symptoms manifest, rabies nearly always results in death due to acute progressive encephalitis. However, numerous control measures have successfully eliminated dog-mediated human rabies deaths in upper-income countries. These include dog population management, parenteral dog vaccination programs, access to human rabies vaccines, and education programs for bite prevention and wound treatment. In most rabies-endemic countries, the vaccination coverage in dogs is low, and dogs are mostly roaming (Jibat *et al.*, 2015; Savadogo *et al.*, 2020). Vaccination is the primary tool to prevent the circulation of rabies in dog populations, but the development of an immune response after vaccination differs between individual dogs. It depends on many factors such as dog characteristics (age at the time of vaccination, sex), management (methods of raising a dog) or vaccination periods (timing of blood sampling), BCS (Body condition score) (Wallace *et al.*, 2020; Manzano *et al.*, 2024; Yale *et al.*, 2021; Wera *et al.*, 2021; 2022). In Vietnam, the strategy of widespread rabies vaccination for dogs, combined with long-term planning and post-vaccination antibody monitoring, is recognized as a crucial approach to the success of the rabies prevention and control program, which aims to prevent the transmission of the rabies virus from animals to humans (Ministry of Agriculture and Rural Development of Vietnam, 2021). However, rabies cases have increased in recent years despite the authorities' efforts. Numerous incidents of rabies resulting from dog bites have been reported in Vietnam. The challenges in fully controlling rabies can be attributed to vaccination coverage falling short of the target (70% of the total dog population) in many areas, as well as significant variability in antibody levels following vaccination (Vietnam government electronic information portal, 2024) (Vietnam national rabies prevention program for the period 2022–2030, 2021). Within the scope of this study, we recorded factors considered to be associated with post-vaccination antibody titers, such as age, rearing method, rearing region, sex, and vaccination time, as these factors are known to be related to animal health, sex, and duration of immunity. The findings of this study underscore the need for adjusting revaccination schedules, as they provide insights that can be used to assess vaccine efficacy and educate dog owners on appropriate rearing methods to enhance rabies prevention and control, as well as to prevent and minimize rabies transmission within dog populations and to humans.

RESEARCH METHODS

STUDY DESIGN AND AREA: A cross-sectional study, a robust method chosen to provide a snapshot of the population at a specific point in time, was conducted in An Giang Province (Figure 1), Vietnam, from September 2023 to April 2024. This design was instrumental in evaluating the efficacy of the Rabisin@ vaccine. A retrospective approach was also employed to collect data on antibody persistence, enabling the assessment of factors influencing post-rabies vaccination immune responses in domestic dogs.



Figure 1: Map of the research site (An Giang Province, Viet Nam).



Figure 2: Experimental design flow for rabies vaccine efficacy study (Thrusfield, 2007).

EXPERIMENTAL DESIGN

STUDY POPULATION: The study included all available healthy dogs aged 3 months and older from dog-owning households in three rural suburbs and urban areas in An Giang Province. Sick dogs were excluded from the study to avoid potential confounding factors that illness might introduce, which could affect the immune response and skew the results. Additionally, to prevent stressful miscarriages during blood collection, pregnant dogs were not allowed to participate in the study.

VACCINE INFORMATION: The Rabies vaccine for dogs is Rabisin@ of Navetco Company (Vietnam), injected subcutaneously or intramuscularly with a dose of 1 ml/head, only vaccinated for completely healthy cattle

(Navetco Animal Health, 2023). Vaccines require strict cold chain management, with storage and transportation at a consistent temperature between 2-8°C. Exposure to freezing temperatures and direct sunlight should be avoided to ensure optimal vaccine quality. In this study, these conditions were carefully controlled and monitored to maintain the integrity of the Rabisin vaccine, thereby enhancing the scientific robustness of the study. The composition and content of the Rabisin rabies vaccine are detailed in Table 1.

Table 1: Composition and content of the Rabisin rabies vaccine.

Ingredients	Content
Rabies virus glycoprotein	≥ 1 IU
Thiomersal	0.1 mg
Alum colloid (Hydroxide form)	1.7 mg
Excipients are enough for 1 dose	Excipients are enough for 1 dose

SAMPLING METHOD

SAMPLE SIZE CALCULATION: A minimum sample size of 323 was determined using Thrusfield's formula, accounting for a predicted positive rate of 70% and a 95% confidence level (Thrusfield, 2007).

RANDOMIZATION: Dogs were meticulously selected using stratified sampling to ensure representation across different geographical areas and rearing methods. The stratification was based on predefined categories, including urban vs. rural areas and dog-rearing practices (Confined, Free-ranging, Semi-confined). Within each stratum, dogs were carefully selected to maintain proportional representation, minimizing the potential for sampling bias and instilling confidence in the study's reliability.

POTENTIAL BIASES: While stratified sampling helped ensure diversity in the sample, there is a potential bias related to the geographical selection. Certain regions might have varying levels of dog ownership practices or access to veterinary services, which could influence the study's findings. These factors were considered when designing the sampling strategy, and efforts were made to mitigate such biases by evenly distributing the sample across all identified strata.

BLOOD SAMPLING: Blood samples were collected from the jugular vein of each dog under aseptic conditions, with utmost care and respect for the animals. Samples were immediately stored at -20°C until analysis, ensuring the preservation of the samples' integrity.

DATA COLLECTION

QUESTIONNAIRE SURVEY: A standardized survey, carefully designed to gather comprehensive data on dog

characteristics (age, gender, breed, body condition score), geographical area (urban, rural), dog management practices (captive, free-range, semi-captive), and vaccination history, was used in this study.

SEROLOGICAL TESTING

ELISA TESTING: Antibody levels were measured using the PLATELIA® RAGE-BIO-RAD ELISA kit, adhering to the manufacturer's protocol. This kit utilizes an indirect ELISA method, introducing serum samples to wells coated with inactivated rabies virus antigens. If antibodies are present, they bind to the antigens. After washing, a protein A conjugate linked to an enzyme is added, which binds to the captured antibodies and forms a complex. The enzyme reaction, initiated by a substrate, produces a color change measured at dual wavelengths (450 nm and 620 nm) for accuracy. This indirect ELISA method was selected for its superior sensitivity and specificity compared to direct ELISA and neutralization assays. It is particularly effective for detecting low concentrations of rabies antibodies. Proper controls were implemented to minimize cross-reactivity and ensure accurate results.

CONTROL STANDARDS: The negative control OD was set below 0.05, and the positive control OD ranged from 0.3 to 1.2. Protective antibody levels were defined as >0.5 EU/mL. The threshold value is the average positive control OD value and must be above 0.5 EU/mL (ELISA Unit). According to OIE and WHO standards, serum samples with antibody levels greater than 0.5 EU/mL are considered protected. This standard is supported by several studies, including those by Batista *et al.* (2011) and Wera *et al.* (2021, 2022).

STATISTICAL ANALYSIS

DATA ANALYSIS: Data were analyzed using Excel for descriptive statistics and Minitab Reference Manual Release 20.3 (Minitab, 2021). The Chi-Square test and two-sample t-test were used to compare proportions and means, respectively. Statistical analysis was conducted using these methods to compare paired factors and identify significant differences. Before applying these tests, assumptions such as the normality of data distribution (for the t-test) and the expected frequency in contingency tables (for the Chi-Square test) were checked. Minitab was used for all statistical analyses, with specific settings adjusted based on the nature of the data, such as confidence intervals set at 95% and significance levels at 0.05.

RESULTS AND DISCUSSION

The community's dog population has received the rabies vaccination, which is a very efficient way to prevent rabies. Nonetheless, the amount of antibodies generated following vaccination is a crucial component, even more so than the

Table 2: Proportion in dogs with protective levels of rabies antibody titres sorted according to geographical area.

Geographical area	No. of Samples	Protective titer	Percentage (%)	χ ² - test (P-Value)	$\bar{x} \pm SE$ (EU/ml)	t-test (P-Value)
(1) Urban	109	90	82.57	(1)(2) =0.743	5.82±0.33	(1)(2) =0.502
(2) Rural	151	119	78.81	(1)(3) =0.451	6.14±0.36	(1)(3) =0.252
(3) Suburban	83	67	80.72	(2)(3) =0.729	5.25±0.37	(2)(3) =0.085
Total	343	276	80.47		5.82±0.21	

vaccination rate in the dog population. The production of antibodies is influenced by various factors, including the pet’s age, gender, genetic characteristics, and constitution, as well as human-related factors, such as management practices, treatment methods, care, and nutritional food. Other contributing factors include the farming areas, ecological regions, vaccination timing, and number of vaccine doses administered. The immune response to rabies vaccination in dogs is a complex and variable process, influenced by many factors. This study examines various factors that influence antibody production in dogs post-vaccination, highlighting the intricate nature of this issue. The purpose of vaccination is not only to protect individual animals from the disease but also to achieve sufficient vaccination coverage to establish herd immunity. Different sources agree that maintaining herd immunity requires a coverage rate exceeding 70% (WHO, 2018; Wallace *et al.*, 2020), and in fact, the WHO recommends that, in endemic countries, canine vaccination coverage should reach at least 70% (Manzano *et al.*, 2024).

GEOGRAPHICAL AREA

The results of surveying the rate and intensity of antibody titers in dogs after vaccination in different geographical areas are shown in Table 2.

The analysis of 343 canine serum samples after Rabisin vaccination revealed that 80.47% (276/343) of the samples exceeded the protective antibody titer threshold. The overall mean antibody titer was 5.82 ± 0.21 EU/mL. When broken down by geographical area, the proportion of dogs with protective titers was 82.57% in urban areas, 78.81% in rural areas, and 80.72% in suburban areas. Although these proportions varied slightly between geographical regions, the differences were not statistically significant, as demonstrated by the χ² test (P>0.05). Similarly, the t-test for pairwise comparisons between urban, rural, and suburban regions indicated no statistically significant differences in the antibody titers (P>0.05). Overall, the data suggests a uniformly high rate of protective antibody response to rabies vaccination across the regions surveyed. The findings of this study demonstrate a high rate of protective antibody titers in dogs across all geographical areas, with 80.47% of the samples surpassing the protective threshold after Rabisin vaccination. This Table 2 result is comparable to the findings of Wera *et al.* (2022), who reported a protective antibody level of 86.81% after vaccination. Similarly, our study’s increase in protective immunity is consistent with

Tuyet *et al.* (2018), who documented a rise from 32.92% to 75.83% following rabies vaccination 22 days post-immunization. However, our findings contrast with those of Bich *et al.* (2017), who reported a much lower rate of protective immunity (14.13%) in stray dogs sampled at slaughterhouses in Can Tho City. The diverse living conditions, care, and vaccination practices in various regions may explain this difference. While our study focused on pet dogs that were likely cared for by owners, Bich *et al.*’s study involved stray dogs, whose vaccination and care may be less consistent, leading to lower immunity levels. The lack of statistically significant differences between urban, rural, and suburban areas regarding protective antibody titers suggests that the rabies vaccination program has been implemented effectively across all regions. One plausible explanation for the uniformity in results across geographical areas is the economic development in An Giang province, which has likely reduced disparities in pet care and vaccination practices. Additionally, the increased access to information and veterinary care has improved the knowledge and practices of pet owners in both urban and rural regions. The results of this study highlight the success of the rabies vaccination program in achieving high levels of protective immunity among dogs. This encouraging outcome underscores the importance of continuing large-scale vaccination efforts, particularly in rural and suburban areas where access to veterinary services may still be relatively limited compared to urban centers. To further strengthen rabies control efforts, it is essential to maintain high vaccination coverage in all regions, with particular attention to rural and suburban areas. Future research should focus on long-term monitoring of vaccination outcomes, particularly in stray dog populations, to better understand the factors influencing lower protective immunity levels in such populations. Additionally, more studies are needed to assess how different living conditions and care practices impact the effectiveness of vaccination programs, to optimize rabies control strategies on a national scale.

AGES OF DOGS

The results of surveying the rate and intensity of antibody titers in dogs of different ages after vaccination are shown in Table 3.

The results from Table 3 reveal a significant variation in antibody titers among dogs of different ages post-vaccination. Dogs under 12 months displayed the lowest antibody levels,

Table 3: Comparison of seroprotection rates in dogs of different ages after vaccination.

Age (months old)	No. of Samples	Protective titer	Percentage (%)	χ^2 - test (P-Value)	$\bar{x} \pm SE$ (EU/ml)	t-test (P-Value)
(1) ≤ 12	72	49	68.06 ^a	(1)(2)=0.001	4.25 $\pm$ 0.42 ^a	(1)(2)=0.001
(2) >12-24	76	68	89.47 ^b	(1)(3)=0.001 (1)(4)=0.370	7.44 $\pm$ 0.49 ^b	(1)(3)=0.001 (1)(4)=0.745
(3) >24-60	105	92	87.62 ^b	(2)(3)=0.701	6.93 $\pm$ 0.32 ^b	(2)(3)=0.360
(4) ≥ 60	90	67	74.44 ^a	(2)(4)=0.013 (3)(4)=0.018	4.42 $\pm$ 0.37 ^a	(2)(4)=0.001 (3)(4)=0.001
Total	343	276	80.47		5.82 $\pm$ 0.21	

Note: Percentage values in the same column with different letters (a, b) are statistically significantly different (with $P < 0.05$).

Table 4: Comparison of the protection levels and neutralizing antibody titers against rabies virus after vaccination among different gender groups of dogs.

Dog gender	No. of Samples	Protective titer	Percentage (%)	χ^2 - test (P-Value)	$\bar{x} \pm SE$ (EU/ml)	t-test (P-Value)
(1) Neutered	120	103	85.83	(1)(2)=0.184	6.15 $\pm$ 0.38	(1)(2)=0.35
(2) Female	95	75	78.95	(1)(3) =0.063 (2)(3) =0.673	5.64 $\pm$ 0.40	(1)(3) =0.31 (2)(3) =0.99
(3) Male	128	98	76.56		5.60 $\pm$ 0.33	
Total	343	276	80.47		5.82 $\pm$ 0.21	

while those aged 12-24 months exhibited the highest. Statistical analysis confirmed significant differences between the youngest and oldest age groups compared to the middle age groups ($p = 0.001$). However, no significant disparities were observed between the youngest and oldest age groups or between the middle age groups. These findings can be attributed to age-related changes in the canine immune system. With their underdeveloped immune systems, young dogs may have a weaker response to vaccination due to incomplete thymus development, a vital organ for T lymphocyte maturation. Conversely, having reached full physical and physiological maturity, adult dogs can generate a more robust immune response. As dogs age, however, their immune function gradually declines due to thymic involution and other age-related factors. This explains the weaker immune response observed in older dogs compared to younger groups. Previous studies by [Gazi and Ak \(2011\)](#); [Vinh et al. \(2016\)](#); [Wallace et al. \(2017\)](#), have also documented significant age-related variations in the canine immune system. Recent research by [Rimal et al. \(2020\)](#) has further elucidated the role of immune senescence in older dogs, providing a mechanistic explanation for the age-related differences in immune response observed in our study. Overall, these results underscore the importance of tailoring vaccination strategies to different age groups. They also highlight the critical need to maintain immune health in older dogs. This is a key takeaway from our research and is essential for ensuring the effectiveness of vaccination programs.

DOG GENDER

The proportion of dog serum samples with protection against the rabies according to sex after vaccination is pre-

sented in [Table 4](#).

The results showed that neutered dogs had the highest proportion of protective antibody levels (85.83%), followed by females (78.95%) and males (76.56%). The average antibody levels by sex were 6.15 ± 0.38 EU/ml in neutered dogs, 5.64 ± 0.40 EU/ml in females, and 5.60 ± 0.33 EU/ml in males. Statistical analysis revealed no significant differences between these groups, as indicated by the P-values from the χ^2 -test and t-test. This suggests that sex does not significantly impact post-vaccination antibody levels in dogs. These findings align with previous studies by [Vinh et al. \(2016\)](#) and [Yale et al. \(2021\)](#), concluding that sex did not influence post-vaccination immunity in dogs. Similarly, [Gazi and Ak \(2011\)](#); [Bich et al. \(2017\)](#); [Nale et al. \(2021\)](#) all reported no significant differences in immune response between male and female dogs after rabies vaccination. While most studies find similar immune responses in male and female dogs, some research suggests potential gender-based differences. [Wera et al. \(2022\)](#) observed slightly higher antibody levels in female dogs, though the difference was not significant. [Yale et al. \(2021\)](#), also explored hormonal influences on immune responses, but their findings were inconclusive. The consistency of our findings with most of the literature reinforces the idea that vaccination protocols should not differ based on sex or reproductive status. Instead, vaccination strategies should be tailored according to other factors such as dosage, schedule, and individual dog characteristics. Future research could further explore the role of particular variations and other biological factors in influencing vaccine responses.

RAISING METHOD

The effects of dog raising method on the protection rate and

rabies antibody titer level after vaccination are shown in Table 5.

Table 5: Effect of dog raising method on protection rate and rabies antibody titer level after vaccination.

Dog management	No. of Samples	Protective titer	Percentage (%)	χ^2 - test (P-Value)	$\bar{x} \pm SE$ (EU/ml)	t-test (P-value)
(1) Free-ranging	152	112	73.68 ^a	(1)(2)= 0.016	5.13 $\pm$ 0.35 ^a	(1)(2)= 0.012
(2) Confined	68	60	88.24 ^b	(1)(3)= 0.029	6.52 $\pm$ 0.42 ^b	(1)(3)= 0.014
(3) Semi-confined	123	104	84.55 ^b	(2)(3)= 0.484	6.29 $\pm$ 0.32 ^b	(2)(3)= 0.657
Total	343	276	80.47		5.82 $\pm$ 0.21	

Note: Percentage values in the same column with different letters (a, b) are statistically significantly different (with $P < 0.05$).

Table 6: Comparison of protection levels and neutralizing antibody titers against the rabies virus across different vaccination periods.

Vaccination periods	No. of Samples	Protective titer	Percentage (%)	χ^2 - test (P-Value)	$\bar{x} \pm SE$ (EU/ml)	t-test (P-Value)
<9 months	143	128	89.51 ^a	<0.001	6.92 $\pm$ 0.33 ^a	<0.001
>9 months	202	148	73.27 ^b		5.09 $\pm$ 0.26 ^b	
Total	343	276	80.47		5.82 $\pm$ 0.21	

Note: Percentage values in the same column with different letters (a, b) are statistically significantly different (with $P < 0.05$).

The results from Table 5 demonstrate a significant influence of management methods on both protection rates and antibody levels against rabies in dogs post-vaccination. Dogs maintained in strictly and semi-strictly managed environments exhibited notably higher protective antibody rates compared to free-roaming dogs. The average antibody levels were significantly higher in strictly and semi-strictly managed dogs than in free-roaming dogs.

These findings align with research by Gazi and Ak (2011), highlighting the impact of living conditions and care regimes on post-vaccination protection. Strictly managed dogs likely benefit from improved access to healthcare and vaccination, leading to a more robust immune response. Conversely, free-roaming dogs may face challenges accessing veterinary care due to unstable living conditions and increased exposure to the natural environment, potentially hindering their immune response. Studies by Vinh et al (2016) and Wallace et al. (2017) further support this notion, indicating that strictly managed dogs tend to have more robust immune systems following vaccination. The significant implications of these results highlight the crucial role of management methods in rabies vaccine effectiveness. This underscores the need for comprehensive vaccination programs tailored to free-roaming dogs. By implementing appropriate management strategies, it is possible to enhance the protection rates and antibody levels against rabies in canine populations, contributing to preventing and controlling this deadly disease.

VACCINATION TIME

The results of the serological survey on protective immunity against rabies in dogs over time post-vaccination (vaccination time).

Results from Table 6 indicate that the time since vac-

nation significantly influences dogs' protection rate and antibody levels. Dogs vaccinated within the previous nine months exhibited a higher protection rate (89.51%) and elevated average antibody levels (6.92 $\pm$ 0.33 EU/ml) compared to those vaccinated more than nine months ago, who had a protection rate of 73.27% and antibody levels of 5.09 $\pm$ 0.26 EU/ml. The difference between these groups was statistically significant ($p < 0.001$), highlighting the decline in antibody levels over time after vaccination. These findings align with previous research, such as studies by Tyakaray et al. (2024) and Wallace et al. (2017), which demonstrated that antibodies peak within 2-4 weeks after vaccination and maintain protective levels for up to a year, with a subsequent decline. This emphasizes the necessity for timely revaccination, as booster doses are critical for maintaining immunity. Similarly, Pimburage et al. (2017) observed that antibodies peaked around day 30 post-vaccination, remained stable until day 180, and then began to decrease. This supports the findings that post-vaccination immunity wanes over time, necessitating regular booster shots to sustain protective levels. The results are further corroborated by studies from Handous et al. (2023) and Jakel et al. (2008), which stressed the importance of booster shots in prolonging protective immunity. These studies collectively reinforce the importance of adhering to recommended vaccination schedules to ensure long-term rabies immunity in dogs. The significant impact of time since vaccination on antibody levels and protection rates highlights the need for regular revaccination. Adhering to appropriate vaccination intervals is crucial for maintaining effective immunity in dogs against rabies.

The study highlights several strategies to address the inconsistencies in rabies vaccination coverage, particularly in resource-limited settings. Establishing mobile vaccination clinics in collaboration with local veterinarians and engag-

ing community leaders in vaccination campaigns are crucial steps. Furthermore, implementing community education programs on the importance of routine vaccination, supported by governmental and non-governmental organizations, could significantly improve vaccination rates. Public awareness campaigns through social media, radio, and community gatherings effectively disseminate the benefits of vaccination. These strategies aim to maintain high vaccination rates and influence public health policies and rabies prevention programs by promoting responsible pet ownership and regular vaccination practices.

CONCLUSIONS AND RECOMMENDATIONS

Factors associated with the immune status of dogs in the population raised in An Giang province include the age of the dogs, dog-keeping methods, and vaccination status. These factors were significantly correlated with the presence of rabies antibodies in the serum of vaccinated dogs. The study recommends maintaining high rabies vaccination coverage of over 70%, adhering to optimal vaccination schedules, and focusing on vaccinating dogs aged 12-24 months. It suggests improving dog-keeping practices and exceptionally confined and semi-free methods to enhance vaccination effectiveness. Additionally, long-term studies on antibody persistence and regular booster vaccinations are needed to maintain protective immunity. These findings align with global trends emphasizing the critical role of high vaccination coverage and proper animal husbandry in controlling rabies. However, compared to other studies, regional variations in antibody persistence suggest the need for tailored vaccination strategies in different settings. For instance, recent studies have shown variability in antibody levels across various geographic regions and dog populations, highlighting the importance of localized research. Future research should focus on long-term studies of antibody persistence, the efficacy of booster vaccinations, and the impact of different dog-keeping practices on vaccination outcomes.

ACKNOWLEDGEMENTS

The research is funded by the Vietnam National University Ho Chi Minh City (VNU-HCM) within the framework of Project Code C202316-12.

NOVELTY STATEMENT

This study analyzes factors influencing rabies vaccine effectiveness in An Giang dogs, aiming to improve rabies prevention through better dog management, timely vaccinations, and ongoing monitoring

Nguyen Phi Bang: Conceived, designed and performed the experiments.

Nguyen Phi Bang, Le Thi Thuy Hang, Nguyen Thi Hanh Chi, Nguyen Thi Bich Hanh: Analyzed the data.

Nguyen Phi Bang, Le Thi Thuy Hang, Nguyen Ba Trung and Ngo Thuy Bao Tran: Wrote the paper.

All authors reviewed and approved the final manuscript.

CONFLICT OF INTEREST

We certify that there is no conflict of interest.

REFERENCES

- Batista HB, Lima FE, Maletich D, Silva AC, Vicentini FK, Roehe LR, Spilki FR, Franco AC, Roehe PM (2011). Immunoperoxidase inhibition assay for rabies antibody detection. *J. Virol. Methods*, 174(1-2): 65-8. <https://doi.org/10.1016/j.jviromet.2011.03.025>
- Bich TN, Hien ND, Vinh TP, Hai NM (2017). Survey of Rabies Virus Antibodies in Dogs at Slaughterhouses in Can Tho City. *Can Tho Univ. J. Sci.*, (50): 77-80.
- Gazi A, Ak S (2011). Detection of Neutralising Antibody Titration in Vaccinated Owned and Stray Dogs against Rabies Virus. *İstanbul Üniv. Vet. Fakültesi Dergisi*, 37(2): 97-106.
- Hampson K, Dushoff J, Cleaveland S, Haydon DT, Kaare M, Packer C, Dobson A (2009). Transmission Dynamics and Prospects for the Elimination of Canine Rabies. *PLoS Biol.*, 7: 0462-0471. <https://doi.org/10.1371/journal.pbio.1000053>
- Handous M, Turki I, Ghram A, BenMaiz S, Bensalem J, Basdouri N, Soltani M, Bassalah F, Kharmachi H. (2023). Evaluation of the immune response of dogs after a mass vaccination campaign against rabies in Tunisia. *BMC Vet Res.* Jan 30;19(1):24. [doi: 10.1186/s12917-023-03582-8](https://doi.org/10.1186/s12917-023-03582-8).
- Hien ND (2012). Survey on immune efficacies of dogs vaccinated by rabigen-mono vaccine in Cantho city. *J. Vet. Sci. Technol.*, XIX(4): 1-6. Accessed from <https://vjol.info.vn/index.php/kk-ty/article/view/9752/8975>
- Hien ND, Vinh TP, Bich TN, Lam NT (2023). Seroprevalence of rabies virus in dogs in the Mekong Delta, Viet Nam. *Int. J. Vet. Sci.* 12(5): 690-694. <https://doi.org/10.5455/OVJ.2023.v13.i6.3>
- Jakel V, König M, Cussler K, Hanschmann K, Thiel HJ. (2008) Factors influencing the antibody response to vaccination against rabies. *Dev Biol (Basel)*. 2008;131:431-7. PMID: 18634505.
- Jibat T, Hogeveen H, Mourits MCM (2015). Review on dog rabies vaccination coverage in Africa: A question of dog accessibility or cost recovery? *PLoS Negl. Trop. Dis.*, 9(2): <https://doi.org/10.1371/journal.pntd.0003447>
- Manzano MD, Cereza J, García J, Yus LJ, Badiola JJ, Echevarria JE, Monzón M (2024). Factors Involved in the Immunological Protection against Rabies Virus in Dogs in Spain. *Vaccines (Basel)*. 12(3):293. <https://doi.org/10.3390/vaccines12030293>

- Ministry of Agriculture and Rural Development of Vietnam (2021). Summary report of the National Program to control and move towards eliminating Rabies, period 2017–2021. No.: 7507/BNN-TY.
- Minitab (2021). Minitab reference manual release 20.3, Minitab Inc.
- Nale JM, Pharande RR, Majee SB, Gandge RS, Sawane MP, Ingle SA (2021). Serosurveillance of rabies antibodies in dogs in Mumbai region by using indirect ELISA. *Comp. Immunol. Microbiol. Infect. Dis.*, 76: 101655. <https://doi.org/10.1016/j.cimid.2021.101655>
- Navetco animal health (2023). Information about Rabisin@ vaccine. Accessed from <https://navetco.com.vn/san-pham/rabisin-125>
- Pimburage R, Gunatilake M, Wimalaratne O (2017). Sero-prevalence of virus neutralizing antibodies for rabies in different groups of dogs following vaccination. *BMC Vet. Res.*, 13: 133. <https://doi.org/10.1186/s12917-017-1038-z>
- Prime Minister's Office (2021). Vietnam national rabies prevention program for the period 2022-2030. No: 2151/QĐ-TTg. Hanoi, Vietnam.
- Rimal S, Ojha KC, Chaisowwong W, Shah Y, Pant DK, Sirimalaisuwan A (2020). Detection of virus-neutralising antibodies and associated factors against rabies in the vaccinated household dogs of Kathmandu Valley, Nepal. *PLoS ONE* 15(4): e0231967. <https://doi.org/10.1371/journal.pone.0231967>
- Savado M, Koné P, Dahourou LD, Manishimwe R, Sow A, Nébié L, Antoine-Moussiaux N, Doulikom B, Bada-Alambéji R (2020). Epidémiologie de la rage et connaissance, attitudes et pratiques des communautés au Burkina Faso. *Revue D'élevage Et De Médecine Veterinaire Des Pays Tropicaux*, 73(2): 133–144. <https://doi.org/10.19182/remvt.31863>
- Son PH, Hien BT (2020). *Veterinary Immunology Textbook*. Hue University Publishing House. 403 pages.
- Thrusfield Michael (2007). *Veterinary epidemiology*. (3rd ed.). *Veterinary Clinical Studies*. University of Edinburgh. Third Edition by Blackwell Science Ltd. Oxford OX4 2DQ UK.
- Tuyet PN, Trinh NTM, Thuy PTT, Son PH (2018). Evaluation of Rabies Vaccine Efficacy in Domesticated Dogs in Minh Hoa District, Quang Binh Province. *J. Agric. Sci. Technol.*, ISSN 2588-1256. 2(2): 767-780.
- Tyakaray VI, Kabir J, Uzoaga G, Kia GSN (2024). Factors associated with rabies immune status of dogs and anti-rabies vaccination of animal health workers in Kano Metropolis Nigeria. *J. Interv. Epidemiol. Public Health*, 7(22).
- Vietnam government electronic information portal (2024). Rabies has increased dramatically, the Ministry of Health recommends. Accessed from <https://xaydungchinhsach.chinhphu.vn/benh-dai-tang-dot-bien-cho-y-te-khuyen-cao-119240313201733817>
- Vinh TP, Hien ND, Khanh NP, Minh LB (2016). Survey of rabies virus antibodies in dogs at some slaughterhouses in Can Tho city. *Journal of Science, Can Tho University. Special Issue: Agriculture*, 2: 162-167.
- Wallace RM, Cliquet F, Fehlner-Gardiner C, Fooks AR, Sabeta CT, Setién AA, Tu C, Vuta V, Yakobson B, Yang DK, Brückner G, Freuling CM, Knopf L, Metlin A, Pozzetti P, Suseno PP, Shadomy SV, Torres G, Vigilato MAN, Abela-Ridder B, Müller T (2020). Role of Oral Rabies Vaccines in the Elimination of Dog-Mediated Human Rabies Deaths. *Emerg. Infect. Dis.*, 26(12):1-9. <https://doi.org/10.3201/eid2612.201266>
- Wallace RM, Pees A, Blanton JB, Moore SM (2017). Risk factors for inadequate antibody response to primary rabies vaccination in dogs under one year of age. *PLoS Negl Trop. Dis.*, 11(7): e0005761. <https://doi.org/10.1371/journal.pntd.0005761>
- Wera E, Warembourg C, Bulu PM, Siko MM, Dürr S (2022). Immune Response After Rabies Vaccination in Owned Free-Roaming Domestic Dogs in Flores Island, Indonesia. *Front. Vet. Sci.*, 9: 868380. <https://doi.org/10.3389/fvets.2022.868380>
- Wera E, Warembourg C, Bulu PM, Siko MM, Dürr S (2021). Loss of binding antibodies against rabies in a vaccinated dog population in Flores Island, Indonesia. *PLoS Negl. Trop. Dis.*, (9): e0009688. <https://doi.org/10.1371/journal.pntd.0009688>
- World health organization (WHO) (2018). Rabies vaccines: WHO position paper – April 2018. *Weekly epidemiological record*, NO 16, Accessed from <https://www.who.int/publications/i/item/who-wer9316-date-12/06>.
- Yale G, Sudarshan S, Taj S, Patchimuthu GI, Mangalanathan BV, Belludi AY, Shampur MN, Krishnaswamy TG, Mazeri S (2021). Investigation of protective level of rabies antibodies in vaccinated dogs in Chennai, India. *Vet. Rec. Open.*, 8(1): e8. <https://doi.org/10.1002/vro2.8>