JAVeST
Journal Of Applied Veterinary Science and Technology

Journal of Applied Veterinary Science and Technology

http://e-journal.unair.ac.id/javest

OPEN ACCESS

Literature Review

Histopathological Analysis of Rabies Disease From 2014 to 2022: A Literature Review

Analisis Histopatologi Penyakit Rabies dari Tahun 2014-2022: Studi Literatur

Afifah Yudining Dwi Andadari[1*], Dyah Ayu Oktavianie A. Pratama[1], Andreas Bandang Hardian[1], Handayu Untari[2]

[1]Laboratory of Veterinary Anatomical Pathology, Faculty of Veterinary Medicine, Universitas Brawijaya, Malang-Indonesia
[2]Laboratory of Veterinary Anatomy, Histology and Embriology, Faculty of Veterinary Medicine, Universitas Brawijaya, Malang-Indonesia

ABSTRACT

Background: Rabies is a contagious and zoonotic disease caused by Lyssavirus, a neurotropic, negative-sense, single-stranded RNA virus. Rabies infects most mammals through the transmission of saliva from a rabid animal that enters the body of a healthy animal through an open wound, bite, scratch, or direct contact. A post-mortem diagnosis and evaluation are crucial for establishing regional statistical data in order to design a robust strategy for combating rabies. Histopathology has long been known to be an invaluable source of information regarding the destructive impact of rabies in nervous tissue. In addition to other ante-mortem evaluations, a correlation between clinical signs, gross pathological findings, and histopathological findings must be established to achieve the maximum target of combating rabies. **Purpose:** This study aims to analyze and compare gross pathological findings and histopathological findings in the literature published between 2014 and 2022. **Methods:** A comparison between gross pathological findings and histopathological findings was conducted on case studies from 2014 to 2022. Anamnesis and clinical signs were obtained as supporting data. The findings were presented as percentage to identify the predominant pathological signs. **Results:** A review of four case studies revealed that paralysis, hyperesthesia, gait abnormality, and muscle tremor were the most commonly observed signs (50%). Only two case studies revealed gross pathological findings, including meningeal congestion and cerebellar hemorrhage. Eight studies identified the intracytoplasmic negri body in Purkinje cells as the most commonly observed histopathological finding (100%). **Conclusion:** The primary clinical signs and gross pathological findings associated with rabies are typically regarded as non-specific. Histopathology revealed the intracytoplasmic Negri body in Purkinje cells as the most commonly observed finding (100%).

ARTICLE INFO

Received: 4 June 2023
Revised: 18 January 204
Accepted: 13 Maret 2024
Online: 30 April 2024

***Correspondence:**
Afifah Yudining Dwi Andadari
E-mail: afiandadari@gmail.com

Keywords: Cerebellum; Histopathology; Lyssavirus; Negri Body; Rabies

ABSTRAK

Latar Belakang: Rabies merupakan penyakit menular dan zoonosis yang disebabkan oleh *Lyssavirus*, yang berjenis neurotropik, *negative-sense*, dan virus RNA untai tunggal. Rabies menginfeksi sebagian besar mamalia melalui transmisi air liur dari hewan rabies yang memasuki tubuh hewan yang sehat melalui luka terbuka, gigitan, goresan, atau kontak langsung. Diagnosis dan evaluasi *post-mortem* sangat penting untuk menetapkan data statistik regional untuk merancang strategi yang kuat untuk memerangi rabies. Histopatologi telah lama dikenal sebagai sumber informasi yang tak ternilai mengenai dampak destruktif rabies pada jaringan saraf. Selain evaluasi *ante-mortem* lainnya, korelasi antara tanda-tanda klinis, temuan patologis kasar, dan temuan histopatologis harus ditetapkan untuk mencapai target maksimum memerangi rabies. **Tujuan:** Studi ini bertujuan untuk menganalisis dan membandingkan temuan patologis anatomi dan temuan histopatologis dalam literatur yang diterbitkan antara tahun 2014 dan 2022. **Metode:** Perbandingan antara temuan patologi anatomi, dan temuan histopatologis dilakukan pada studi kasus dari 2014 hingga 2022. Anamnesis dan tanda-tanda klinis diperoleh sebagai data pendukung. Temuan disajikan sebagai persentase untuk mengidentifikasi tanda-tanda patologis yang dominan. **Hasil:** Tinjauan dari empat studi kasus menunjukkan adanya bahwa kelumpuhan, hiperestesia, kelainan gaya berjalan, dan tremor otot merupakan tanda-tanda yang paling sering diamati (50%). Hanya dua studi kasus yang mengungkapkan adanya temuan patologi makroskopik, termasuk kongesti meningeal dan perdarahan pada otak kecil. Delapan penelitian mengidentifikasi adanya *negri bodies intracytoplasmic* dalam sel Purkinje, yang merupakan temuan histopatologis yang paling sering diamati (100%). **Kesimpulan:** Tanda-tanda klinis primer dan temuan patologis makroskopis yang terkait dengan rabies biasanya dianggap sebagai non-spesifik. Histopatologi menunjukkan bahwa *negri bodies intracytoplasmic* dalam sel Purkinje sebagai temuan yang paling sering ditemukan (100%).

Cite This Article:
Andadari, A.Y.D., Pratama, D.A.O.A., Hardian, A.B., and Untari, H. 2024. ***Histopathological Analysis Of Rabies Disease From 2014 to 2022: A Literature Review.*** Journal of Applied Veterinary Science and Technology. 5(1): 93-98. https://doi.org/10.20473/javest.V5.I1.2024.93-98

Kata kunci: Cerebellum; Histopathologi; Lyssavirus; Negri Body; Rabies

INTRODUCTION

The word rabies is derived from the Latin word rabere, which means to lose sanity. This contagious disease was first identified in the 1880s by Louis Pasteur. Rabies in mammals causes fatal damage due to the involvement of the nervous system, driven by the negative-sense RNA virus belonging to the Lyssavirus genus and the Rhabdoviridae family. Rabies is a viral and zoonotic disease that can be prevented by vaccination. Nevertheless, rabies remains a significant public health concern, particularly in Indonesia. This is because rabies is responsible for the deaths of 60,000 individuals worldwide, despite the administration of prophylactic vaccines to 15 million individuals following exposure annually. Rabies is prevalent across all continents, with a mortality rate of over 95% in Asia and Africa (Singh *et al.*, 2017).

The first cases of rabies reported in Indonesia were identified in buffalo in West Java (Esser, 1884) and dogs (Penning, 1889). Currently, 25 provinces in Indonesia are affected by rabies. Overcoming rabies in Indonesia is challenging due to its close association with animal-to-human contact, increasing demand for animal-derived protein, virus mutation patterns, and high mobility patterns of Indonesian citizens. Over the past decades, various efforts to control rabies in Indonesia have been made, including dissemination and advocacy programs to the citizens, anti-rabies vaccine and serum distribution, and diagnosis-based integrated epidemiological investigation (Putra, 2018).

REVIEWS

Data were obtained from eight case studies on rabies in animals published between 2014 and 2022. **Table 1** summarizes the case histories and clinical symptoms of rabies. Four out of eight case studies included in this review did not mention any clinical symptoms, while the remaining four case studies mentioned clinical signs associated with neurological, locomotor, and behavioral abnormalities. The most frequently mentioned clinical symptoms in the case studies included hypersalivation (75%), paralysis (50%), hyperesthesia (50%), gait abnormality (50%), tremor and muscle stiffness (50%), ataxia (25%), tachycardia (25%), teeth grinding (25%), agitation (25%), and stupor (25%). In addition, four out of eight case studies did not mention any gross pathological findings. However, Rahman *et al.*, (2015) identified meningeal congestion and cerebellar hemorrhage as gross pathological findings (**Figure 1**). In comparison, Coelho *et al.*, (2022) identified hemorrhage in the white matter of the spinal cord.

Histopathological evaluations using the hematoxylin and eosin (HE) staining revealed the appearance of intracytoplasmic eosinophilic Negri body in Purkinje cells as the most frequently observed abnormality (100%), followed by the appearance of perivascular cuffing (87.5%). Other abnormalities were also observed, including satellitosis, gliosis, and neuronophagia (62,5%), meningitis (50%), meningeal vessel congestion (37.5%) and Purkinje cell necrosis (12.5%) (**Table 2**).

Table 1. Case history and clinical signs of rabies cases in animals

No.	Case History	Clinical Signs	References
1.	10 brain samples of buffalo with a history of canine bite from March 2012 to September 2014	Ataxia, hyperesthesia, hypersalivation, paralysis, gait abnormality	Rahman *et al.* (2015)
2.	34 brain samples of animals suspected of having rabies (11 buffalo, 8 cattle, 13 dogs, 1 cat, 1 horse) from June 2012 to June 2013	Not mentioned	Sharma *et al.* (2014)
3.	50 brain samples of animals (22 dogs, 16 buffalo, 7 cattle, 1 donkey, 3 mongooses, 1 deer)	Not mentioned	Beigh *et al.* (2017)
4.	57 brain samples from 2007 to 2011	Not mentioned	Beck *et al.* (2017)
5.	11 brain samples obtained from animals clinically suspected of having rabies	Hypersalivation, hyperesthesia, aggressiveness, gait abnormality, mandibular paralysis	Hananeh *et al.* (2015)
6.	11 dogs aged less than six months suspected of having rabies	Hypersalivation, hyperesthesia, aggressiveness, gait abnormality, mandibular paralysis	Arunlanandam *et al.* (2020)
7.	Calves aged eight months with neurological and behavioral disorders	Hypersalivation, head tilting, asymmetrical gait	Sharif *et al.* (2022)
8.	Horse aged four years with sudden neurological disorder	Right hind limb stiffness, muscle tremor, teeth grinding	Coelho *et al.* (2022)

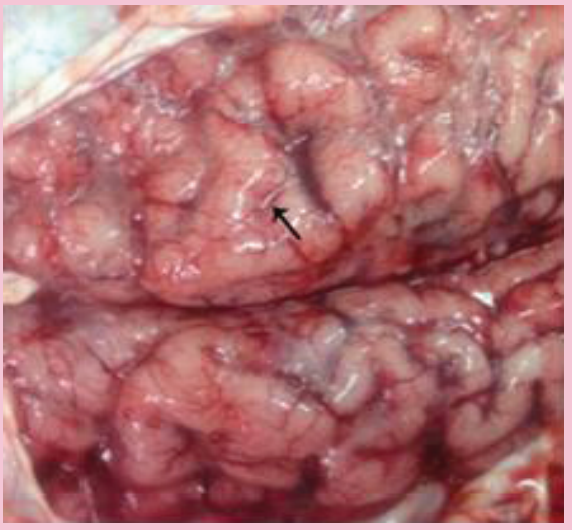

Figure 1. Meningeal vessel congestion in buffalo (black arrow) (Rahman *et al.* 2015)

The eight case studies included in this review revealed the appearance of Negri body in Purkinje cells. Negri body is a cytoplasmic inclusion that present as a solid eosinophilic mass with disseminated granules and an oval to round shape (**Figure 2**). It can be found in large neuron cells, primarily in the pyramidal layer of the hippocampus and within Purkinje cells located between the granular and molecular layers of the cerebellum (Hatanpaa and Kim, 2014). The negri body defined as a viral RNA protein aggregate situated within the cytoplasm of the cell (hence its name, intracytoplasmic), is a key indicator of rabies when diagnosing the disease using histopathology with HE staining. The presence of a negri

Table 2. Gross pathological and histopathological findings in rabid

No.	Gross Pathological Findings	Histopathological Findings	References
1.	Severe meningeal congestion, cerebellar hemorrhage	Intracytoplasmic Negri body in Purkinje cells, neuronal necrosis, satellitosis, gliosis, neuronophagia, meningeal congestion and hemorrhage, lymphocytic infiltration of meninges (meningitis)	Rahman *et al.* (2015)
2.	Not mentioned	Intracytoplasmic Negri body in neurons and Purkinje cells in all of the brain samples, perivascular lymphocytic cuffing in 7 samples, neuronophagia in 5 samples, gliosis in 12 samples, and satellitosis and meningitis in 12 samples	Sharma *et al.* (2014)
3.	Not mentioned	Negri body in Purkinje cells and hippocampal neurons, perivascular cuffing, neuronophagia, meningitis, gliosis, congestion, satellitosis	Beigh *et al.* (2017)
4.	Not mentioned	Perivascular cuffing in 47 samples, gliosis in 50 samples, satellitosis and neuronophagia in 51 samples, Negri body in 32 samples.	Beck *et al.* (2017)
5.	Not mentioned	Negri body in 5 out of 11 samples, meningoencephalitis (nonsuppurative), perivascular cuffing, lymphocytic meningitis, Purkinje cell and neuronal cell necrosis	Hananeh *et al.* (2015)
6.	No pathological findings	Gliosis, neuronophagia, hemorrhage, satellitosis, perivascular cuffing, intracytoplasmic eosinophilic Negri body, meningeal vessel congestion	Arulanandam *et al.* (2020)
7.	No pathological findings	Perivascular cuffing, lymphocytic encephalitis, intracytoplasmic eosinophilic Negri body in cerebellar Purkinje cells	Sharif *et al.* (2021)
8.	Hemorrhage in the white matter of the spinal cord	Lymphocytic perivascular cuffing, intracytoplasmic eosinophilic Negri body in cerebellar Purkinje cells, as well as the pons and thalamus neuron	Coelho *et al.* (2022)

body depends on the viral load within the organ. A lower viral load results in a more severe encephalitis lesion and a greater abundance of Negri body. Conversely, a higher viral load result in a less severe encephalitis lesion due to the high mortality rate before the virus is capable of developing a negri body (Salbahaga *et al.*, 2012).

DISCUSSION

Histopathological evaluations using HE staining cannot be considered as a stand-alone method for confirming the diagnosis of rabies. Other methods must be considered, including ante-mortem and post-mortem examinations, fluorescence antibody test (FAT), polymerase chain reaction (PCR) test, mouse inoculation test (MIT), and immunohistochemistry (IHC) test. This review indicated that FAT was used in 37.5% of the case studies, whereas PCR and MIT were used in 25% and 12.5% of the case studies, respectively.

Clinical signs in rabid animals result from disturbances to the nervous system. Hypersalivation appeared as the most common neurological symptom in rabid animals (75%). This is caused by the disruption of postganglionic parasympathetic nerve fibers due to viral replication. Hypersalivation was observed in 50% of the case studies involving buffalo, cattle, dogs, horses, cats, and puppies. This indicates that no significant correlation was observed between species, age, and the appearance of clinical symptoms. Kook (2013) suggested that

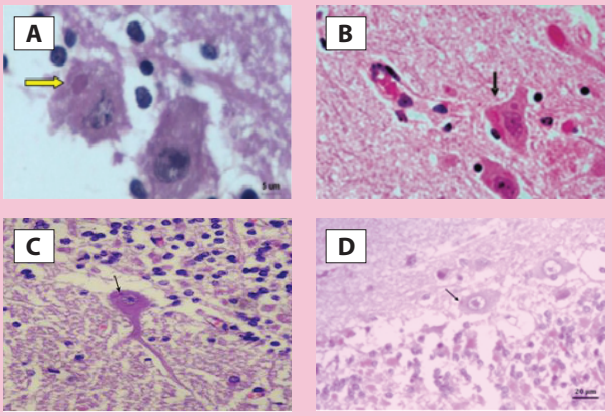

Figure 2. (A). Negri body in the hippocampus of a puppy (yellow arrow) (H.E staining at a 1000x magnification) (Arulanandam *et al.* 2020); **(B).** Negri body in the hippocampus of cattle (black arrow) (H.E staining at a 400x magnification) (Beigh *et al.* 2017); **(C).** Negri body in the brain of a buffalo (black arrow) (H.E staining at 100x magnification) (Rahman *et al.* 2015); **(D).** Negri body in the spinal cord of a horse (black arrow) (H.E staining at a 400x magnification) (Coelho *et al.* 2022).

sialorrhea or hypersalivation is a normal condition in pediatric animals during the oral neuromuscular development, ranging from 18 to 24 months old. Once the animals reach adulthood, hypersalivation becomes abnormal and is associated with pathological conditions. Furthermore, paralysis is the second most frequently observed symptom in 50% of the case studies. Paralysis is defined as a condition of complete loss of motor function. Paralysis typically begins with ataxia, a decreased ability to control muscle that leads to involuntary motor movements. Paralysis and ataxia are clinical signs that result from the disruption to the spinal cord. Paralysis and ataxia in rabid animals is attributed to the rabies virus which attaches to the G protein receptor in target cells (myocytes, local motor, and sensory neurons) as well as amplification in myocytes (Ettinger *et al.*, 2016; Singh *et al.*, 2017).

Gross pathological findings revealed the presence of meningeal congestion and cerebellar hemorrhage. Congestion and hemorrhage are pathological lesions caused by hemostasis and perfusion disturbances in vascular tissue. Hemorrhage occurs due to functional abnormalities of either endothelial cells, platelets, or coagulation factors. In contrast, congestion occurs due to an alteration in blood flow, which leads to an accumulation of blood within the vessels. This is typically due to vasodilatation, increased blood flow, or decreased blood outflow in cases of obstruction (Zachary, 2017).

The rabies virus, which infects the central nervous system, alters the metabolic requirements, resulting in an increased blood supply to the brain. This leads to vasodilatation and blood accumulation in the brain and its surrounding tissue. The Beta-2 receptor in blood vessels is responsible for the vasodilatation and the subsequent control of the vessel diameter when stimulated by epinephrine. One possible explanation for endothelial damage is due to the release of cytotoxic

mediators, which play a crucial role in maintaining the integrity of endothelial cells, such as tumor necrosis factor (TNF) (Rahman *et al.*, 2015).

Perivascular cuffing lesion is the second most common finding in rabid animals. Perivascular cuffing is defined as the accumulation of lymphocytes around blood vessels as a manifestation of inflammation or immunity response (**Figure 3**). Typically, this inflammation occurs with gliosis in the brain of rabid animals. Perivascular cuffing arises as a response to seal the infected cells to secure the healthy cells in their surrounding environment. According to Berata *et al.*, (2014), perivascular cuffing is predominantly characterized by the accumulation of lymphocytes, macrophages, and plasma cells. Another lesion commonly found in rabid Animal is gliosis (**Figure 4**). Gliosis, also known as Babes nodule, is defined as glial cell proliferation with a mild infiltration of leukocytes and plasma cells in infected neurons. Glial cells have phagocytic characteristics and are typically associated with the presence of inclusion body around the neurons. Gliosis is a common response to damage or pathological conditions in the brain to isolate the damaged tissue, enhance tissue integrity, and limit the spread of inflammation and death of neurons. Gliosis is regulated by the release of damage-associated molecular patterns (DAMPs) stimulated by dead cells (Mahaling, 2022; Salbahaga *et al.*, 2012).

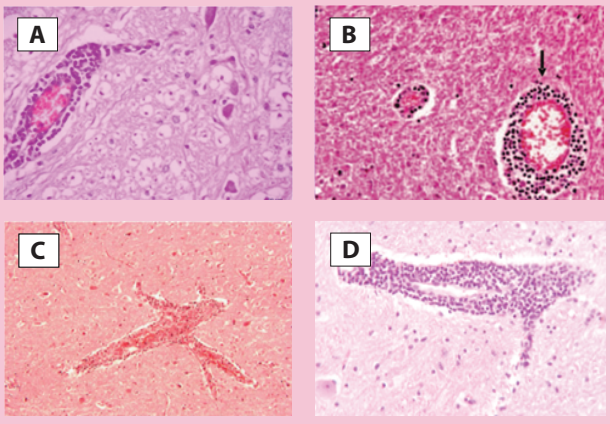

Figure 3. (A). Perivascular cuffing in the spinal cord of a horse dominated with lymphocytes and plasma cells (black arrow) (H.E staining at a 400x magnification) (Coelho *et al.*, 2022); **(B).** Perivascular cuffing in the cerebellum of a buffalo (black arrow) (H.E staining at a 1000x magnification) (Beigh *et al.*, 2017); **(C).** Perivascular cuffing in the brain of a dog (black arrow) (H.E staining at a magnification of 100x) (Beck *et al.*, 2017); **(D).** Perivascular cuffing in the brain of calf (black arrow) (H.E staining at a 400x magnification) (Sharif *et al.*, 2021).

Satellite cells belong to the oligodendrocytes located in the grey matter in the central nervous system (CNS) that regulates perineuronal areas. When rabies virus damages the CNS and its surrounding areas due to damage to the neurons, the satellite cells undergo hypertrophy and proliferation, or known as satellitosis. In the HE staining, the satellite cells are similar to lymphocytes due to their nuclear morphology and cytoplasmic volume (Zachary, 2017). Meanwhile, neuronophagia is defined as the phagocytosis of microglial cells surrounding dead neurons due to infection. Typically, following neuronal necrosis, perineuronal edema occurs, which results in a hollow space due to the loss of the neuronal cell body. On histopathological examination, neuronophagia appears as a necrotic neuronal body surrounded by macrophages that phagocytize debris cells (**Figure 6**) (Zachary 2017). The final and least frequently observed lesion is meningitis. Leptomeningitis is a type of meningitis that typically occurs in rabid animals. It refers to the inflammation of the subarachnoid space. The inflammatory cell infiltration associated with this condition is typically dominated by lymphocytes, monocytes, and a small amount of plasma cells (**Figure 7**) (Bassuino *et al.*, 2016).

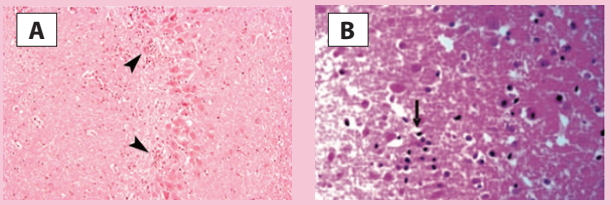

Figure 4. (A). Multifocal gliosis in the hippocampus of canine (black arrow) (HE staining at a 100x magnification) (Beck, 2017); **(B).** Gliosis in the hippocampus of canine (HE staining at 400x magnification) (Beigh *et al.*, 2017).

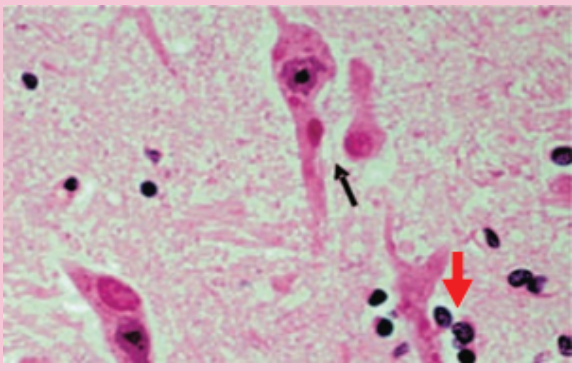

Figure 5. Hippocampus of rabid cow showing intracytoplasmic eosinophilic Negri bodies and satellitosis (arrows) (Beigh *et al.*, 2017).

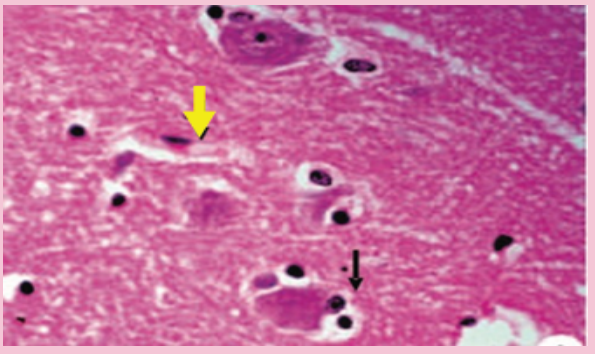

Figure 6. Neuronophagia in the hippocampus of a dog (yellow arrow) using H.E staining at a 1000x magnification) (Beigh *et al.*, 2017).

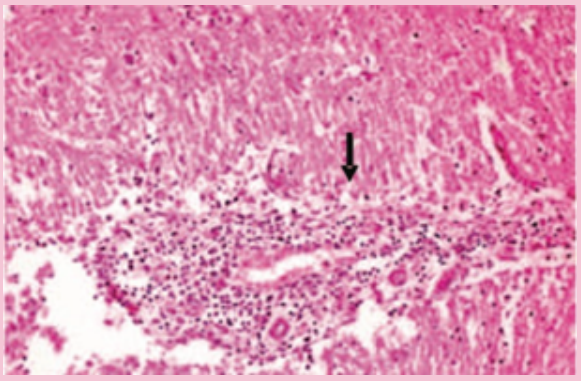

Figure 5. Meningitis in the cerebellum of a buffalo (black arrow) using HE staining at a 400x magnification (Beigh *et al.*, 2017).

CONCLUSION

The clinical manifestations of rabies infection in various animal species have been associated with damage to the nervous system, such as hypersalivation (75%), paralysis (50%), hyperesthesia (50%), gait abnormality (50%), tremor and muscle stiffness (50%), ataxia (25%), tachycardia (25%), teeth grinding (25%), agitation (25%), and stupor (25%). However, no significant correlation was observed between signalment, history, and clinical manifestations that appear as signs of rabid animal. During necropsy, the gross pathological findings included meningeal congestion, cerebellar hemorrhage, and hemorrhage in the white matter of the spinal cord. Meanwhile, the histopathological findings using the HE staining included eosinophilic intracytoplasmic Negri body in Purkinje cells (100%), perivascular cuffing (87.5%), satellitosis, gliosis, and neuronophagia (62.5%), meningitis (50%), meningeal vessel congestion (37.5%), and Purkinje cell necrosis (12.5%).

ACKNOWLEDGEMENT

The author would like to thank all parties who have assisted in writing this literature review.

AUTHORS CONTRIBUTION

All authors were involved in preparation, writing and data processing

CONFLICT OF INTEREST

The author declares that there is no conflict of interest with the parties involved in this literature review.

FUNDING INFORMATION

In this article no external funding or financial support was provided for the literature review.

REFERENCES

Arulanandam, K., Sridhar, R., Thangapandiyan, M., and Balachandran, C., 2020. Pathology of Rabies in Pup Mortality. *International Journal of Current Microbiology and Applied Sciences*, 9(6), 4252–4255.

Bano, I., Sajjad, H., Shah, A. M., Leghari, A., Mirbahar, K. H., Shams, S., and Soomro, M., 2017. A Review of Rabies Disease, its Transmission and Treatment. *Journal of Animal Health and Production*, 4(4), 140–144.

Beck, S., Gunawardena, P., Horton, D. L., Hicks, D. J., Marston, D. A., Ortiz-Pelaez, A., Fooks, A. R., and Núñez, A., 2017. Pathobiological Investigation of Naturally Infected Canine Rabies Cases from Sri Lanka. *BMC Veterinary Research*, 13(1), 1-9.

Beigh, A. B., Sandhu, B. S., Singh, C. K., Gupta, K., and Sood, N. K., 2017. Histopathological Lesions Associated with Rabies in Nervous Tissue of Animals. *Indian Journal of Veterinary Pathology*, 41(3), 179-183.

Coelho, C. S., d'El Rei Passos Sodré, T., Freitas, M. D., Moroz, L. R., Nunes, T. L., da Cunha Peixoto, T., and Leal, P. V., 2022. Rabies in a Previously Vaccinated Horse: Case Report. *Acta Veterinaria Brasilica*, 16(2), 84–89.

Ettinger, S. J., Feldman, E. C., and Cote, E., 2016. Textbook of Veterinary Internal Medicine. 8th Edition. Elsevier.

Hananeh, W. M., Nassir, I. M., Ababneh, M. M. K., Hailat, N. Q., and Brown, C. C., 2015. Pathological and Molecular Diagnosis of Rabies in Clinically Suspected Food Animals Using Different Diagnostic Tests. *Large Animal Review*, 21(2), 243–250.

Hatanpaa, K. J., and Kim, J. H., 2014. Neuropathology of Viral Infections. In Handbook of Clinical Neurology: Elsevier , Vol. 123, 93–214.

Berata, K.I., Kardena, M. I., Winaya, I.B.O., Supartika, I.K.E., 2014. Kombinasi Lesi Badan Negri, Spongiform, dan Perivascular Cuffing pada Otak Anjing Penderita Rabies. *Jurnal Veteriner Indonesia,* 15(3), 363-369.

Kook, P. H., 2013. Ptyalism in Dogs and Cats-A Short Review. *Zurich Open Repository and Archive*, 1-4.

Lu, X. X., Zhu, W. Y., and Wu, G. Z., 2018. Rabies Virus Transmission via Solid Organs or Tissue Allotransplantation. *In Infectious Diseases of Poverty,* 7(1), 1-8.

Mahaling, B., 2022. DAMPs and Gliosis. Annals of Immunology and Immunotherapy, 4(1), 1-8.

Putra, K. S. A., 2018. Epidemiology of Rabies. *International Journal of Chemical & Material Sciences*. 1 (1), 14-24.

Rahman, S. A. El, Elbeskawy, M., and Hamed, M. F., 2015. Detection of Rabies Virus and its Pathological Changes in Brain of Buffaloes in Egypt. *Advances in Animal and Veterinary Sciences,* 3(11), 588–593.

Rohde, R. E., and Rupprecht, C. E., 2020. Update on Lyssaviruses and Rabies: Will Past Progress Play as Prologue in the Near Term Towards Future Elimination. *Faculty Reviews,* 9 (9), 1-18.

Salbahaga, D. P., Supartika, I.K.E., and Berata., 2012. Distribusi Lesi Negri's Bodies dan Peradangan pada Otak Anjing Penderita Rabies di Bali. *Indonesia Medicus Veterinus,* 1(3), 352–360.

Sharif, M., Arhaiem, A., Giadan, O., Adam, A., Abdalla, F., Dayhum, A., and Bengoumi, M., 2021. Rabies in Bovine: First Case Report of Rabies in Al Jabal Al Akhdar, Libya. *Open Veterinary Journal,* 11(1), 96–99.

Singh, R., Singh, K. P., Cherian, S., Saminathan, M., Kapoor, S., Reddy, G. B. M., Panda, S., and Dhama, K., 2017. Rabies–Epidemiology, Pathogenesis, Public Health Concerns and Advances in Diagnosis and Control: A Comprehensive Review. *In Veterinary Quarterly*, 37 (1), 212–251.