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Original Article
Small Animal Diseases

Study of meningeal enhancement in magnetic resonance imaging in dogs with central nervous system diseases[1]

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ABSTRACT.- Guedes C.H., Sousa M.P., Moraes A.R.D.P., Filadelpho A.L. & Machado V.M.V. 2024. **Study of meningeal enhancement on magnetic resonance imaging of dogs with central nervous system diseases.** *Pesquisa Veterinária Brasileira 44:e07127, 2024.* Departamento Cirurgia Veterinária e Reprodução Animal, Faculdade de Medicina Veterinária e Zootecnia, Universidade Estadual Paulista "Júlio de Mesquita Filho", Rua Prof. Doutor Walter Mauricio Correa s/n, Cx. Postal 560, Botucatu, SP 18618-681, Brazil E-mail: charleshguedes@gmail.com

Magnetic resonance imaging (MRI) plays an important role in detecting and characterizing meningeal lesions, thus assisting in a possible *ante mortem* clinical diagnosis of intracranial diseases. Meningeal enhancement has been described as a sign of multiple central nervous system (CNS) disorders. The aim of this study was to evaluate meningeal enhancement on MRI of the brain of dogs and to associate them with different CNS diseases. A retrospective study of 22 dogs submitted to MRI was carried out, with a history of clinical signs of neurological diseases as an inclusion criterion for selecting these animals for the study. The data were divided according to the age and sex of the animals, and the analysis criteria were regarding the CNS diseases found, location, pattern and definition of meningeal enhancement. The results demonstrate that encephalitis and neoplasia occur more frequently among the diseases observed, with 22.7% of clinical suspicions. The site with the highest incidence was the parietal/temporal/frontal, with a 27.3% prevalence, followed by the frontal, with 18.2%. Regarding the meningeal pattern, it was found that there was 90.9% more enhancement in the pial and dural regions together than when comparing them individually. When evaluating the definition of meningeal enhancement, slight enhancement was most observed (59.1%). The present study made it possible to obtain specific information and better understand the characteristics of meningeal enhancement, including two patterns of meningeal enhancement (pial and dural) and identifying the association of values in different CNS diseases in dogs.

INDEX TERMS: Brain, magnetic resonance, veterinary neurology, small animals, central nervous system.

RESUMO.- [**Estudo do realce meníngeo em imagem de ressonância magnética de cães com enfermidades do sistema nervoso central.**] A ressonância magnética (RM) tem papel importante na detecção e caracterização das lesões meníngeas, auxiliando um possível diagnóstico clínico *ante mortem* de doenças intracranianas. O realce meníngeo tem sido descrito como um sinal de múltiplas enfermidades do sistema nervoso central (SNC). O objetivo deste estudo foi avaliar o realce meníngeo nas RM do encéfalo de cães e associá-las às diferentes doenças do SNC. Foi realizado um estudo retrospectivo de 22 cães

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submetidos ao exame de RM, com o histórico de sinais clínicos de doença neurológica como critério de inclusão para seleção destes animais ao estudo. Os dados foram divididos de acordo com a idade e sexo dos animais e os critérios de análise foram, quanto às enfermidades do SNC encontradas, local, padrão e definição do realce da meninge. Os resultados obtidos demonstram que, dentre as doenças observadas, a encefalite e a neoplasia ocorrem com maior frequência, ambas com 22,7% de suspeitas clínicas. O local de maior incidência foi determinado como sendo o parietal/temporal/frontal, com 27,3% de prevalência, seguido do frontal com 18,2%. Com relação ao padrão da meninge, foi verificado que houve 90,9% mais realce na região pial e dural conjuntamente do que ao compará-las individualmente. Já ao avaliar a definição do realce meníngeo, o mais observado foi o realce discreto (59,1%). O presente estudo possibilitou a obtenção de informações específicas e maior compreensão das características do realce meningeal, incluindo dois padrões de realce meníngeo (pial e dural) e a identificação da associação dos valores nas diferentes doenças do SNC em cães.

TERMOS DE INDEXAÇÃO: Encéfalo, ressonância magnética, neurologia veterinária, pequenos animais, sistema nervoso central.

INTRODUCTION

Technological advances in different diagnostic imaging methods available worldwide demonstrate a high potential for acquiring increasingly better images, contributing to an early and accurate diagnosis of patients (Cook & Cook 2009). Magnetic resonance imaging (MRI) is a highly accurate diagnostic method that evaluates the different organs in great detail (Hage et al. 2010). It became the method of choice for evaluating the brain and adjacent structures, as it is a non-invasive exam that allows anatomical evaluations in diverse sequences in different neurological diseases (McGowan 2008).

The meninges line the entire central nervous system (CNS), forming a chamber where the cerebrospinal fluid (CSF) is present, important in maintaining constant and homogeneous intracranial pressure, being composed of three layers: dura mater, pia mater and arachnoid (Summers et al. 1995). Meningeal enhancement, seen on imaging, has been described as a radiological sign of multiple diseases, and depending on its characterization and interpretation, it can contribute to a diagnosis (Smirniotopoulos et al. 2007). The pattern of the meninges can be divided into two types: pachymeninges, where there is detachment of the dura mater, and leptomeninges, which correspond to the pia mater and arachnoid (Souza 2016).

The pachymeningeal pattern is identified in the dural reflections of the falx cerebri, the tentorium, the falx cerebelli and the cavernous sinus. It is typically thick and can be linear or nodular. Conversely, the leptomeninges follow the brain's pial surface and line the grooves and cistern's subarachnoid space. It is recognized with a gyriform or serpentine appearance. Slight degrees of enhancement of both are considered normal in dogs (Lamb et al. 2014).

Some characteristics of the meningeal enhancement pattern provide guidance for differential diagnoses. In the last two decades, numerous investigations have been carried out to define the characteristics of neoplasms and inflammatory and cerebrovascular diseases on MRI. These data have been used in veterinary medicine to diagnose presumptively and determine a treatment (Wolfe et al. 2011). This information is especially important in cases where abnormal meningeal enhancement is the only obvious alteration; however, the literature is still scarce (Kirmi et al. 2009).

Some of the brain diseases with diagnosis established by imaging tests already described in the literature are malformations, such as ventriculomegaly, identified as common in English Bulldogs (Ryan et al. 2014); IV ventricle arachnoid diverticulum with syringohydromyelia (Bazelle et al. 2015); 21 cases of ischemic stroke in Greyhound dogs (Kent et al. 2014); 50 cases of traumatic brain injury in dogs (Beltran et al. 2014); cholesteatoma with meningoencephalitis (Newman et al. 2015); epidural abscesses (Linon et al. 2014) or neosporosis (Parzefall et al. 2014).

Therefore, it is important to know the different patterns of meningeal enhancement concerning brain diseases since the adequate characterization of the pattern of meningeal enhancement (hypersignal) may be safer for interpreting MR images.

The aim of this study was to evaluate the MR images of animals with a history of clinical neurological signs and to characterize the enhancement of the meningeal enhancement signal with its underlying cause. Investigations of these patterns in specific diseases contribute to diagnosing CNS diseases in dogs and cats.

MATERIALS AND METHODS

Ethical approval. The present study complies with the Committee on Ethics for the Use of Animals (CEUA-Unesp) under protocol 0714/2019. The study was carried out in the imaging laboratory of the Department of Veterinary Surgery and Animal Reproduction of the "Faculdade de Medicina Veterinária e Zootecnia" (FMVZ) of "Universidade Estadual Paulista 'Júlio de Mesquita Filho'" (Unesp), Botucatu.

Animals. This study comprises a retrospective study of MRI scans of 22 dogs with clinical symptoms of neurological disease, treated at the university hospital of the FMVZ-Unesp, from January 2018 to December 2020. Based on the neuroanatomical diagnosis of only one patient, a list of differential diagnoses was established from diseases that could affect the anatomical region in question, classifying them into categories inserted in the acronym DINAMIT V, that is, degenerative (D), inflammatory/infectious diseases (I), neoplastic or nutritional (N), developmental anomalies (congenital) (A), metabolic (M), idiopathic (I), traumatic or toxic (T) and vascular (V) (Pellegrino et al. 2011). There was no follow-up of the patients after performing the imaging exams.

Magnetic resonance scan. An Esaote® equipment, model Vet-MR Large 0.25T, with four radiofrequency channels, was used. Pulse sequences weighted in FSE T2, FSE T1, FLAIR, and GE T2 were instituted to obtain brain images using contrast in the transverse, sagittal and coronal planes in 3mm slices. The radiofrequency coil used was the C-shaped coil model. The images were collected and evaluated with the help of the Synapse PACS digital image diagnostic program.

The diseases that can cause changes in the physical characteristics of the brain tissue on the MR image in this study followed the descriptions presented by Thomas et al. (1996), Kraft & Gavin (1999) and Snyder et al. (2006).

Procedure. For the definition of meningeal enhancement in the different clinical suspicions of central nervous system diseases, each exam was separated and analyzed by three evaluators, and the final evaluation was the one that was repeated two or three times. Data collection and analysis were performed using Microsoft Excel software.

Data analysis. Based on the MRI scans of the dogs' skulls, the frequency distribution of meningeal enhancement was carried out regarding central nervous system diseases, location, meningeal pattern and definition of enhancement. The Chi-square test ($p<0.05$) was applied to compare the proportions found, when applicable, using the BioEstat program.

RESULTS

After tabulating and analyzing all the data obtained individually by each of the three evaluators and finally determining the diagnosis based on the criterion of repeating the same signs two or three times, the data obtained were grouped in tables for better understanding. Table 1 shows the total number of animals diagnosed with each of the eight diseases recorded in this study. Also, it correlates this data with the definition of enhancement (marked, moderate and mild) analyzed in the MRI scan.

It was observed that encephalitis and neoplasms were more frequent ($p<0.0001$), both with a prevalence of 22.7%. There was no statistically significant difference ($p>0.05$) for ventricular dilatation and meningoencephalitis (13.6% each). Meningitis and meningoencephalitis of unknown origin (MUO) were the clinical suspects with the lowest percentage of observation in the meningeal enhancement study (4.5%). The most observed definition was discrete (59.1%), statistically superior to moderate (22.7%) and marked (18.2%), which did not differ by Chi-square test ($p>0.05$). Figure 1-3 show the different meningeal thicknesses. It can also be seen that the data showed that only the diseases encephalitis and granulomatous meningoencephalitis (MEG) showed marked definitions of meningeal enhancement. In contrast, most of the diseases showed discrete definitions of enhancement, with encephalitis (in addition to marked definition) and neoplasms showing the highest frequency of this definition.

Regarding the pattern of enhancement definition separately, there was a statistical difference ($p<0.0001$) in the frequency of simultaneous enhancement of the pial and dural regions when assessed separately. There was a 90.9% enhancement in these regions when assessed together. Considering this pattern, there was a higher enhancement frequency for encephalitis, neoplasia, and ventricular dilatation. For meningoencephalitis, enhancement in this pattern was also found in the pial region, and for meningitis, enhancement was only observed in the dural region, as described in Table 2.

The Chi-square test ($p<0.0001$) showed that the highest frequency of correlation with the evaluated site was parietal/temporal/frontal, statistically higher than the other sites, not differing only from frontal (18.2%).

There was no statistically significant difference in the frequency of enhancement observations in the sites according to each disease.

Table 1. Correlation between meningeal enhancement definition characteristics and different clinical suspicions of the animals submitted to the magnetic resonance imaging (MRI) examination by the Chi-square test ($p<0.05$)

Clinical suspicion	Meningeal enhancement definition				Total percentage (100%)
	Accentuated	Average	Discreet	Total number of animals	
Ventricular dilation	0	2	1	3	13.6
Encephalitis	2	0	3	5	22.7
Granulomatous meningoencephalitis	2	0	0	2	9.1
Meningioma	0	0	2	2	9.1
Meningitis	0	0	1	1	4.5
Meningoencephalitis	0	1	2	3	13.6
MUO	0	0	1	1	4.5
Neoplasm	0	2	3	5	22.7
TOTAL	4	5	13	22	100

MUO = meningoencephalitis of unknown origin.

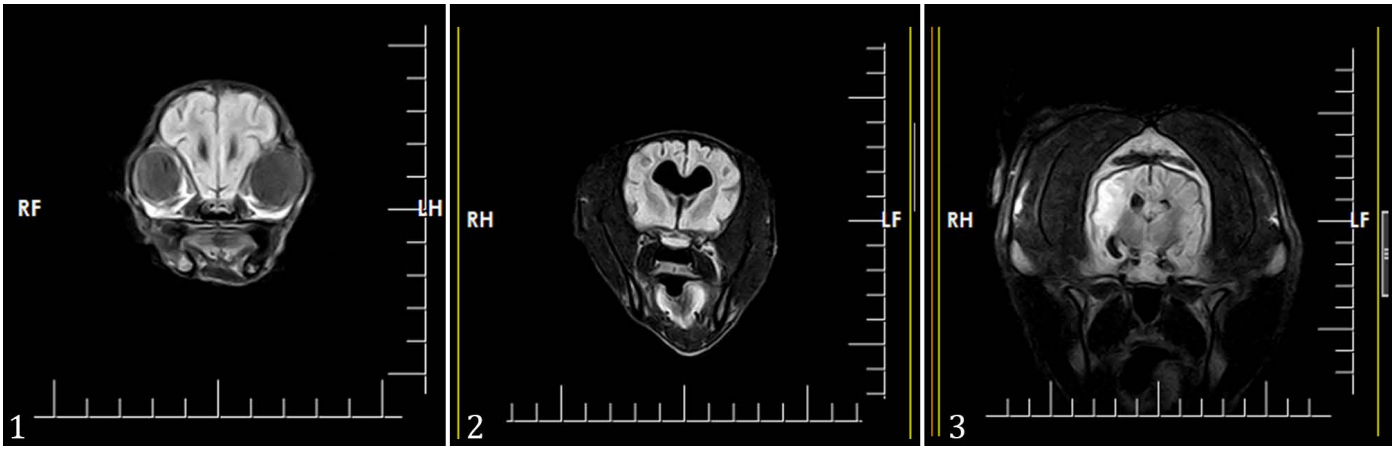

Fig.1-3. Enhancement definition images. (**1**) Marked, (**2**) medium, and (**3**) discreet meningeal enhancement.

DISCUSSION

CNS diseases represent a significant cause of death in dogs, as agreed by Song et al. (2013), Bentley (2015) and Bueno (2018). Understanding the functions of the main areas of the nervous system is essential to recognize how neurological diseases manifest (Cook & Cook 2009). The present study finds that the information contained in the MRI is capable of detecting intracranial diseases, based on the observation of meningeal enhancement, as described by Smirniotopoulos et al. (2007), who state in their studies that meningeal enhancement is described as an imaging sign of multiple CNS diseases.

In the MRI scans performed on the 22 dogs, clinical suspicions included ventricular dilatation, encephalitis, granulomatous meningoencephalitis, meningioma, meningitis, meningoencephalitis, MUO and neoplasia, based on the retrospective analysis of cases treated at a university hospital from 2018 to 2020. Encephalitis and granulomatous meningoencephalitis were observed in the most pronounced form regarding the definition of meningeal enhancement. Ventricular dilation, encephalitis, meningioma, meningitis, meningoencephalitis, MUO, and neoplasia were seen in discrete form. Dilation, meningoencephalitis, and neoplasia were seen in the intermediate (medium) form.

With regard to pathologies, a higher frequency of encephalitis and neoplasms was observed, each representing 22.7% of cases, which partially agrees with Hecht & Adams (2010), who describe infectious causes as the most recurrent in their studies. It corroborates with the hypotheses of LeCourter & Withrow (2007) and Snyder et al. (2006) that there are primary intracranial neoplasms that affect small animals, but less frequently. In contrast, metastatic neoplasms were described more frequently in the present study. Among secondary neoplasms, the most common was lymphoma, similar to that reported by Rossmeisl Jr. (2010).

Neoplasm is the third most important cause in this study, and it also proves to be a significant cause of neurological dysfunction, affecting mainly middle-aged and elderly dogs, similar to what was reported by Santos et al. (2012). In Brazil, this prevalence is lower, probably due to the high frequency of infectious diseases and lower life expectancy of dogs (Cherubini et al. 2005, Hecht & Adams 2010), also demonstrated in our study.

Considering the data shown in Table 3, we can see that the site of greatest involvement was the parietal/temporal/frontal with 27.3% of the cases and also that the ones with the lowest rate of development were the parietal/occipital and the temporal corresponding to 4.5% of cases each.

The main signs of the meninges in the two patterns presented were also evaluated for the different diseases, the majority with identical values for pial and dural enhancement individually but with rates of 90% for the appearance of joint enhancement

Table 2. Correlation between the meningeal pattern and the different clinical suspicions of animals submitted to magnetic resonance imaging (MRI) examination by the Chi-square test ($p<0.05$)

Clinical suspicion	Meningeal pattern			
	Dural	Pial	Pial and dural	Total
Ventricular dilation	0	0	3 (13.6%)	3
Encephalitis	0	0	5 (22.7%)	5
Granulomatous meningoencephalitis	0	0	2 (9.1%)	2
Meningioma	0	0	2 (9.1%)	2
Meningitis	1 (4.5%)	0	0	1
Meningoencephalitis	0	1 (4.5%)	2 (9.1%)	3
MUO	0	0	1 (4.5%)	1
Neoplasm	0	0	5 (22.7%)	5
TOTAL	1 (4.5%)	1 (4.5%)	20(90.9%)	22

MUO = meningoencephalitis of unknown origin.

Table 3. Frequency of meningeal enhancement sites in relation to different clinical suspicions in animals submitted to magnetic resonance imaging (MRI) examination

Clinical suspicion	Meningeal enhancement sites								
	(F)	(P)	(T)	F/T	F/P	F/T/P	P/T	P/O	Total
Ventricular dilation	0	0	0	0	1	1	1	0	3
Encephalitis	1	1	0	2	0	1	0	0	5
Granulomatous meningoencephalitis	0	0	0	0	0	2	0	0	2
Meningioma	1	1	0	0	0	0	0	0	2
Meningitis	1	0	0	0	0	0	0	0	1
Meningoencephalitis	0	1	0	0	0	0	2	0	3
MUO	0	0	0	0	0	0	0	1	1
Neoplasm	1	0	1	0	1	2	0	0	5
TOTAL	4 (18.2%)	3 (13.6%)	1 (4.5%)	2 (9.1%)	2 (9.1%)	6 (27.3%)	3 (13.6%)	1 (4.5%)	22

MUO = meningoencefalite de origem desconhecida, F = frontal, P = parietal, T = temporal, O = occipital.

for both. Mellema et al. (2002) demonstrate in their studies that meningeal enhancement (dural and pial) was identified in dogs in MRI, related to several diseases such as bacterial and fungal meningitis, plasmacytic meningitis associated with an accumulation of subdural fluid, granulomatous meningoencephalitis, inflammation secondary to otitis internal inflammation, feline infectious peritonitis and neoplasia.

This research, as it is a retrospective study, did not follow the development of the animals after the diagnosis and initiation of treatment, being restricted to the period of data collection from the imaging exams. Thus, survival data of the studied animals, as well as prognoses and disease development, are not available.

CONCLUSION

The alterations seen in the magnetic resonance imaging (MRI) exams of the meninges of the evaluated animals demonstrate a correlation with the neurological clinical signs that they presented, affirming the capacity of this exam in the diagnosis of intracranial diseases, being necessary for more studies for the exact determination of the characteristics of the image in each of the diseases. It is suggested that other MRI findings related to these diseases be verified, and other diagnostic methods for different diseases should be associated with them.

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Conflict of interest statement.- The authors declare that there are no conflicts of interest.

REFERENCES

Bazelle J., Caine A., Palus V., Summers B.A. & Cherubini G.B. 2015. MRI. Characteristics of fourth ventricle arachnoid diverticula in five dogs. Vet. Radiol. Ultrasound 56(2):196-203. <https://dx.doi.org/10.1111/vru.12218> <PMid:25385344>

Beltran E., Platt S.R., Mcconnel J.F., Dennis R., Keys D.A. & De Risio L. 2014. Prognostic value of early magnetic resonance imaging in dogs after traumatic brain injury: 50 cases. J. Vet. Intern. Med. 28(4):1256-1262. <https://dx.doi.org/10.1111/jvim.12368> <PMid:24814522>

Bentley R.T. 2015. Magnetic resonance imaging diagnosis of brain tumors in dogs. Vet. J. 205(2):204-216. <https://dx.doi.org/10.1016/j.tvjl.2015.01.025> <PMid:25792181>

Bueno L.M.C. 2018. Estudo das enfermidades encefálicas diagnosticadas por ressonância magnética. Tese de Doutorado, Universidade Estadual Paulista "Julio Mesquita Filho", Botucatu, SP. 61p.

Cherubini G.B., Mantis P., Martinez T.A., Lamb C.R. & Cappello R. 2005. Utility of magnetic resonance imaging for distinguishing neoplastic from nonneoplastic brain lesions in dogs and cats. Vet. Radiol. Ultrasound 46(5):384-387. <https://dx.doi.org/10.1111/j.1740-8261.2005.00069.x> <PMid:16250394>

Cook C.R. & Cook J.L. 2009. Diagnostic imaging of canine elbow dysplasia: a review. Vet. Surg. 38(2):144-153. <https://dx.doi.org/10.1111/j.1532-950X.2008.00481.x> <PMid:19236671>

Hage M.C.F.N.S., Iwasaki M., Rabbani S.R., Kamikawa L., Cervantes H.J.R., Bombonato P.P., Sterman F.A. & Otaduy M.C.G. 2010. Imagem por ressonância magnética na investigação da cabeça de cães. Pesq. Vet. Bras. 30(7):593-604. <https://dx.doi.org/10.1590/S0100-736X2010000700014>

Hecht S. & Adams W. 2010. MRI of Brain disease in veterinary patients part 2: acquired brain disorders. Vet. Clin. N. Am., Small Anim. Pract. 40(1):39-63. <https://dx.doi.org/10.1016/j.cvsm.2009.09.006> <PMid:19942056>

Kent M., Glass E.N., Haley A.C., March P., Rozanski E.A., Galban E.M., Bertalan A. & Platt S.R. 2014. Ischemic stroke in Greyhounds: 21 cases (2007-2013). J. Am. Vet. Med. Assoc. 245(1):113-117. <https://dx.doi.org/10.2460/javma.245.1.113> <PMid:24941395>

Kirmi O., Sheerin F. & Patel N. 2009. Imaging of the meninges and the extra-axial spaces. Seminars Ultrasound CT MRI 30(6):565-593. <https://dx.doi.org/10.1053/j.sult.2009.08.007> <PMid:20099640>

Kraft S.L. & Gavin P.R. 1999. Intracranial neoplasia. Clin. Tech. Small Anim. Pract. 14(2):112-123. <https://dx.doi.org/10.1016/S1096-2867(99)80009-7> <PMid:10361361>

Lamb W.F., Steinberger J.K., Bows-Larkin A., Peters G.P., Roberts J.T. & Wood F.R. 2014. Transitions in pathways of human development and carbon emissions. Environ. Res. Lett. 9:014011. <https://dx.doi.org/10.1088/1748-9326/9/1/014011>

LeCourter R.A. & Withrow S.J. 2007. Tumors of the nervous system, p.659-685. In: Withrow S.J. & Vail D.M. (Eds), Withrow & MacEwen's Small Animal Clinical Oncology. 4th ed. Saunders Elsevier, Canada. <https://dx.doi.org/10.1016/B978-072160558-6.50032-0>

Linon E., Geissbuhler U., Karli P. & Forterre F. 2014. Atlantoaxial epidural abscess secondary to grass awn migration in a dog. Vet. Comp. Orthop. Traumatol. 27(2):155-158. <https://dx.doi.org/10.3415/VCOT-13-07-0095> <PMid:24493255>

McGowan J.C. 2008. Basic principles of magnetic resonance imaging. Neuroimag. Clin. N. Am. 18(4):623-636. <https://dx.doi.org/10.1016/j.nic.2008.06.004> <PMid:19068405>

Mellema L.M., Samii V.F., Vernau K.M. & LeCouteur R.A. 2002. Meningeal enhancement on magnetic resonance imaging in 15 dogs and 3 cats. Vet. Radiol. Ultrasound 43(1):10-15. <https://dx.doi.org/10.1111/j.1740-8261.2002.tb00435.x> <PMid:11866038>

Newman A.W., Estey C.M., Mcdonough S., Cerda-Gonzalez S., Larsen M. & Stokol T. 2015. Cholesteatoma and meningoencephalitis in a dog with chronic otitis externa. Am. Soc. Vet. Clin. Pathol. 44(1):157-163. <https://dx.doi.org/10.1111/vcp.12212> <PMid:25385218>

Parzefall B., Driver C.J., Benigni L. & Davies E. 2014. Magnetic resonance imaging characteristics in four dogs with central nervous system neosporosis. Vet. Radiol. Ultrasound 55(5):539-546. <https://dx.doi.org/10.1111/vru.12160> <PMid:24766225>

Pellegrino F.C., Pacheco E.L. & Vazzoler M.L. 2011. Caracterización de los trastornos neurológicos en los perros: 1652 casos (marzo 2008-junio 2010). Parte I. Revta Arg. Neurol. 2(1):78-96.

Rossmeisl Jr. J.H. 2010. Vestibular disease in dogs and cats. Vet. Clin. N. Am., Small Anim. Pract. 40(1):81-100. <https://dx.doi.org/10.1016/j.cvsm.2009.09.007> <PMid:19942058>

Ryan C.T., Glass E.N., Seiler G., Zwingenberger A.L. & Mai W. 2014. Magnetic resonance imaging findings associated with lateral cerebral ventriculomegaly in English Bulldogs. Vet. Radiol. Ultrasound 55(3):292-299. <https://dx.doi.org/10.1111/vru.12123> <PMid:24320744>

Santos R.P., Fighera R.A., Beckmann D.V., Brum J.S., Ripplinger A., Neto D.P, Baumhardt R. & Mazzanti A. 2012. Neoplasmas envolvendo o sistema nervoso central de cães: 26 casos (2003-2011). Pesq. Vet. Bras. 32(2):153-158. <https://dx.doi.org/10.1590/S0100-736X2012000200011>

Smirniotopoulos J.G., Murphy F.M., Apressando E.J., Rees J.H. & Schroeder J.W. 2007. Patterns of contrast enhancement in the brain and meninges. Radiographics 27(2):525-551. <https://dx.doi.org/10.1148/rg.272065155> <PMid:17374867>

Snyder J.M., Shofer F.S., Van Winkle T.J. & Massicotte C. 2006. Canine intracranial primary neoplasia: 173 cases (1986-2003). J. Vet. Intern. Med. 20(3):669-675. <https://dx.doi.org/10.1892/0891-6640(2006)20[669:cipnc]2.0.co;2> <PMid:16734106>

Song R.B., Vite C.H., Bradley C.W. & Cross J.R. 2013. Postmortem evaluation of 435 cases of intracranial neoplasia in dogs and relationship of neoplasm with breed, age, and body weight. J. Vet. Intern. Med. 27(5):1143-1152. <https://dx.doi.org/10.1111/jvim.12136> <PMid:23865437>

Souza T.A. 2016. Ressonância Magnética nos Estudos de Patologias em Animais. Trabalho de Conclusão de Curso, Universidade Paulista, São Paulo. p.15. Available at <https://monografias.brasilescola.uol.com.br/saude/ressonancia-magnetica-nos-estudos-de-patologias-em-animais.htm> Accessed on Aug. 7 2021.

Summers B.A., Cummings J.F. & De Lahunta A. 1995. Veterinary Neuropathology. Mosby, Michigan. 527p.

Thomas W.B., Wheeler S.J., Kramer R. & Kornegay J.N. 1996. Magnetic resonance imaging features of primary brain tumors in dogs. Vet. Radiol. Ultrasound 37(1):20-27. <https://dx.doi.org/10.1111/j.1740-8261.1996.tb00807.x>

Wolfe T.D., Pillai S.P.S., Hildreth III B.E., Lanigan L.G., Martin C.K., Werbeck J.L. & Rosol T.J. 2011. Effect of zoledronic acid and amputation on bone invasion and lung metastasis of canine osteosarcoma in nude mice. Clin. Exp. Metastasis 28(4):377-389. <https://dx.doi.org/10.1007/s10585-011-9377-9> <PMid:21374084>