TITLE: Can MRI differentiate between ring-enhancing gliomas and intra-axial abscesses?

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ABSTRACT

Gliomas of the brain may appear as expansile ring-enhancing masses in magnetic resonance imaging (MRI) studies, mimicking the appearance of intra-axial abscesses. The aims of this study were to compare the MRI features of ring-enhancing gliomas and intra-axial brain abscesses in dogs and cats and to identify the characteristics that might help differentiate them. For this multicenter, retrospective, and observational study, inclusion criteria were the following: a) a definitive diagnosis of glioma or abscess based on cytological or histopathological examination following CSF collection or surgical biopsy/necropsy, respectively; b) MRI study performed with a high or low field MRI scanner, including a same plane T1W pre- and post-contrast, a T2W and a T2 FLAIR sequence in at least one plane. If available, delayed T1W post-contrast, T2*W GE, DWI/ADC and SWI sequences were also evaluated. Sixteen patients were diagnosed with ring-enhancing gliomas and 15 with intra-axial abscesses. A homogenous signal on T1W ($P = 0.049$) and T2W ($P = 0.042$) sequences, a T2W ($P = 0.005$) or T2*W GE ($P = 0.046$) peripheral hypointense halo and an even enhancing capsule ($P = 0.002$) were significantly associated with brain abscesses. A progressive central enhancement on delayed T1W post-contrast sequences was correlated with ring-enhancing gliomas ($P = 0.009$). The combination of the following features was suggestive of brain abscess: homogeneous T1W or T2W signal intensity, a T2W or T2*W GE peripheral hypointense halo and an evenly enhancing capsule. Central progression of enhancement on delayed T1W post-contrast sequences was suggestive of glioma.

INTRODUCTION

Gliomas are primary neuroepithelial tumors accounting for approximately 35–37% of all primary brain tumors in dogs.[1,2] Glial tumors are less common in cats, representing approximately 8% of feline primary brain tumors.[3] Commonly reported MRI features of gliomas have included single, intra-axial, T1-weighted (T1W) iso- to hypointense and T2-weighted (T2W) iso- to hyperintense to normal brain parenchyma lesions, with cyst-like or necrotic areas and variable distribution and degree of contrast enhancement.[1,4-7] An intratumoral hemorrhagic component has also been reported.[6] Brain abscesses are uncommon in companion animals and may develop via a hematogenous spread of bacteria, direct invasion/contiguity, or contamination of cerebrospinal fluid.[8-15] A brain abscess originates as a localized area of neutrophilic cerebritis which, if untreated, may progress into liquefactive necrosis containing viable and degenerate neutrophils (pus) surrounded within 1 to 2 weeks by a well-vascularized fibrovascular capsule.[8,9] On MRI, a brain abscess has been reported as a focal, T2W hyperintense and T1W hypointense lesion compared to normal brain parenchyma, with a necrotic non-enhancing center, surrounded by a thick and strongly contrast-enhancing peripheral rim.[11-13,15,16]

A recent review in the veterinary literature reports up to 45% of gliomas having partial or complete ring-enhancement;[17] therefore, gliomas may appear as expansile ring-enhancing masses, mimicking the radiological appearance of intra-axial abscesses.[18] In human medicine, multiple MRI studies using specific sequences have attempted to find unique characteristics to distinguish between ring-enhancing gliomas and abscesses. A hypointense peripheral capsule on T2W images caused by paramagnetic free radicals within phagocytic macrophages, often associated with susceptibility artifact in T2W gradient echo (T2*) and with a “double rim sign” in susceptibility-weighted imaging (SWI), is considered a distinguishing feature of brain abscesses in humans.[19,20] Abscesses commonly show restricted

diffusion in diffusion weighted imaging (DWI) while gliomas usually do not.[18, 21-23] However, overlapping imaging features have been reported.[24-26] Since the two diseases require very different treatment and have a different prognosis, a correct imaging interpretation is paramount.[13,17,27,28]

The aims of the current study were to compare the MRI features of confirmed ring-enhancing gliomas and intra-axial brain abscesses in dogs and cats and to identify the imaging features that might help to differentiate them. Authors hypotheses were 1) some MRI qualitative characteristics would be associated with brain abscess/glioma classification and, 2) a threshold value for the ratio between lesion diameter and capsule thickness in T1W post-contrast sequences could be used as a cut-off for discriminating between brain abscesses and gliomas.

MATERIALS AND METHODS

CASE SELECTION CRITERIA

This was a multicenter, retrospective, observational study. All animals included were client-owned and underwent MRI examinations of the brain as part of their clinical workup. Previous informed written consent was obtained from all dog owners. All the procedures performed complied with the European legislation "on the protection of animals used for scientific purposes" (Directive 2010/63/EU).

The databases of the Veterinary Hospital "I Portoni Rossi" Anicura Italy, the Veterinary Teaching Hospital of the University of Bern, the Royal Veterinary College, the University of Glasgow, the University of Montreal, the Veterinary Clinic "Neurología Veterinaria" and the Veterinary Hospital "Gregorio VII" were searched for dogs and cats diagnosed with a single ring-enhancing intra-axial lesion. All hospitals approved the use of their imaging data for this project.

Inclusion criteria for this study were the following: (1) a definitive diagnosis of glioma or abscess based on cytological or histopathological examination following CSF collection or surgical biopsy/necropsy, respectively; (2) a MRI study performed with a high or low field MRI scanner, including at least a same plane pre- and postcontrast T1W and a T2W sequence in at least one plane as well as a T2 FLAIR sequence in any plane. If available, T2*W GE, DWI/ADC, SWI and delayed postcontrast T1W sequences were analyzed. The final decisions for subject inclusion or exclusion were made by an ACVR board-certified radiologist (SS) and a second-year ECVDI resident (AC).

MEDICAL RECORD DATA RECORDING:

Medical record entries were retrieved and evaluated by an ACVR board-certified radiologist (SS) and a second-year ECVDI resident (AC). The reports of necropsy, surgical biopsy and/or CSF analysis along with patients' age, sex, and breed were recorded. Because the aim of the study was to describe the MRI features of brain abscesses and to compare them with ring-enhancing gliomas in doubtful cases, the presence of MRI changes related to bite wounds were recorded, but not considered as imaging criteria for including subjects in the study.

IMAGE ANALYSIS

Images were analyzed by an ACVR board-certified radiologist (SS), a ECVN board-certified neurologist (MB) and a second-year ECVDI resident (AC) not blinded to the final diagnosis. The final decision on the imaging characteristics was reached on a consensus basis. The studies were randomly reviewed using a DICOM (i.e., Digital Imaging and Communications in Medicine) viewer program (OsiriX DICOM viewer, Pixmeo, Geneva, Switzerland). The three observers were asked to fill in a pre-defined standardized commercially available

spreadsheet (Microsoft Excel 2020, Microsoft, Redmond, Wash). The following MRI features were assessed: T1W and T2W signal heterogeneity/homogeneity as well as the intensity (hypo-, iso-, hyper-) of the signal compared to normal gray matter on the same sequences; presence of a peripheral hypointense halo on T2W sequences compared to contents of the lesion;[13] presence of a T2 FLAIR attenuated component within the lesion; presence and grade (0, no; 1, mild; 2, moderate; 3, severe) of perilesional white matter edema based on a subjective evaluation; pattern of ring enhancement (even/uneven); presence of progressive central enhancement on delayed post-contrast sequences (delayed post-contrast enhancement was assessed in different planes if the same plane was not available)[29] and the ratio between lesion diameter and maximum capsule thickness in the immediate T1 post contrast images. In cases in which T2*W GE sequences, DWI or SWI were available, additional data were collected such as the presence of susceptibility artifact (i.e., hemorrhage) and a hypointense peripheral halo compared to lesion content in T2*W GE sequences;[16] the presence of abnormal diffusion restriction in DWI/ADC;[18,21] the presence of "dual-rim sign" (defined as two concentric rims at the margins of the lesion with the outer one being hypointense and the inner one hyperintense relative to cavity contents) on SWI images as described previously.[20]

STATISTICAL ANALYSIS

All analyses were performed with commercial software (MedCalc, Software Ltd, Ostend, Belgium) by an experienced statistician (BC). Count data regarding the abscess/glioma diagnosis were crossed referenced with the MRI findings to obtain contingency tables. Chi-square test was applied to analyse data, using Yates correction for 2x2 contingency tables and Fisher's exact test when frequencies inside tables were less than 5. When a significant association ($P<0.05$) was found between an MRI qualitative predictor and abscess/glioma classification, the relative risk and 95% confidence interval (95%CI) were calculated.

The ratio between the lesion diameter and capsule thickness in the immediate T1 post-contrast sequences was analyzed using a receiver-operating characteristic (ROC) approach to identify the cut-off that could best discriminate between abscesses and gliomas. The threshold was calculated using the Youden criterion.[30]

RESULTS

A total of 31 cases met the inclusion criteria. Sixteen patients were diagnosed with ring-enhancing gliomas through necropsy (15/16) or surgical biopsies (1/15); Intra-axial abscesses were diagnosed in 15 patients through necropsy (5/15), CSF analysis (7/15) and surgical biopsies (3/15). Within the abscess group, 6/15 had evidence of bite wounds/penetrating lesions visible as temporal muscle myopathy and calvarial focal defects in continuity/contiguity with the intra-axial mass.

In the ring-enhancing glioma group there were 13 dogs and 3 cats. The canine breeds represented in the study were Boxer (n = 3), French Bulldog (n = 2), Labrador Retriever (n = 2), Jack Russell terrier (n = 2), Lhasa Apso, Boston Terrier, Springer Spaniel and mixed-breed (n = 1 each). Two Domestic short-haired and 1 Sacred Birman cat represented the feline group. Of the 13 dogs, 6 were males (4 neutered) and 7 females (3 spayed). The 3 cats were 2 spayed females and 1 male. The median age was 8 years (range: 5-12) for dogs and 8 years (range: 5-15) for cats.

In the intra-axial abscess group, there were 10 dogs (3 mixed-breed, 1 Boxer, 1 Staffordshire Bull Terrier, 1 West Highland White Terrier, 1 Border Terrier, 1 Miniature Schnauzer, 1 Chihuahua and 1 Golden Retriever) and 5 cats (4 Domestic short-haired and 1 Domestic long-haired cat). Of the 10 dogs 4 were males (1 neutered) and 6 females (3 spayed). The 5 cats were 4 neutered males and 1 spayed female. The median age was 4 years old (range: 1-11) for

dogs and 9 years old (range: 5-12) for cats.

The MRI technical parameters for each institution are listed in Supplement 1 and 2, respectively. The radiofrequency coil selections varied based on patient sizes and availability. All the animals were imaged in sternal recumbency, under general anesthesia. MRI studies were acquired with both low- and high-field MRI scanners. T2*W GE sequences were available in 13 cases of ring-enhancing glioma and in 9 cases of intra-axial abscessation. DWI sequences were obtained in 6 cases with ring-enhancing glioma and in one patient with a brain abscess. SWI was available in only one patient with ring-enhancing glioma. Delayed T1W post-contrast sequences performed at least 5 minutes after the first "immediate" post-contrast sequence were available in 12 glioma cases and in 10 intra-axial abscess cases.

RING-ENHANCING GLIOMAS *vs.* BRAIN ABSCESSES

MRI findings of ring-enhancing gliomas and brain abscesses are summarized in Table 1. Comparisons between groups for MRI characteristics are provided in Table 2. Overall, brain abscesses showed a more homogeneous signal on T1W and T2W sequences compared to ring-enhancing gliomas. A peripheral hypointense halo on T2W and T2*W GE sequences was significantly associated with brain abscesses rather than ring-enhancing gliomas (Figure 1). On postcontrast T1W sequences, abscesses showed a more even ring-enhancing capsule compared to the ring-enhancing gliomas (figure 2), while ring-enhancing gliomas were more likely to have a progressive central enhancement on T1W delayed postcontrast sequences (figure 3). Based on the ROC analysis, a cut-off value of >12 in the ratio between lesion diameter and capsule thickness in the immediate T1 post contrast sequences had a 43.75% sensitivity and 85.71% specificity for the detection of ring-enhancing gliomas. The details of the obtained measurements are provided in supplement 3. The intensity of the lesions

(hyperintense, isointense or hypointense) compared to the gray matter, the presence of a T2 FLAIR attenuating component within the mass, the presence and grade of T2 FLAIR perilesional vasogenic edema, and the presence of intralesional susceptibility artefacts were not statistically significant. The unrestricted or decreased diffusion in DWI/ADC sequence was not statistically evaluated due to the low number of patients where this sequence was available. However, 6/6 patients with ring-enhancing glioma and DWI/ADC available showed unrestricted diffusion; whereas the lesion in the only patient with DWI/ADC available images within the brain abscesses group was characterized by restriction to diffusion (figure 2).

DISCUSSION

Our study showed that ring-enhancing gliomas share several MRI features with intra-axial brain abscesses. However, findings supported our first hypothesis in that some qualitative MRI characteristics were significantly associated with brain abscess or ring-enhancing glioma: a homogenous signal on T1W and T2W sequences, a T2W and T2*W GE peripheral hypointense halo, and an even enhancing capsule were more likely associated with brain abscesses. Progressive central enhancement on T1W delayed postcontrast sequences was strongly associated with ring-enhancing gliomas while this feature was only present in a single dog with a brain abscess. Findings also supported our second hypothesis in that a threshold value of >12 for the ratio between lesion diameter and capsule thickness in T1 post-contrast sequences was found to be a cut-off for discriminating between abscesses and gliomas. The presence of bite wounds/penetrating lesions in continuity/contiguity with an intra-axial mass makes a brain abscess the most likely differential diagnosis. However, we did not consider them as imaging criteria because we aimed to focus on those MRI findings that can help the clinician in a doubtful clinical situation.

In our cohort of patients, brain abscesses had a significantly more homogeneous signal on T1W and T2W sequences, likely reflecting the presence of necrotic/fluid content in the abscess.[11-13,15,16] In contrast, ring-enhancing gliomas usually showed a more heterogeneous T1W or T2W signal due to the presence of variable content in these tumors, including hemorrhage, necrotic tumor tissue, cysts or altered cellular density.[5-7,17,31]

There was absence of statistical significance in the evaluation of the type of T1W and T2W signal compared to the grey matter in both gliomas and abscesses. This is related to the tumor heterogeneity in gliomas and the variable ratio between cellular/protein content in abscesses depending on their chronicity stage, respectively. During their development, abscesses begin as a focal area of cerebritis histologically defined by a perivascular infiltration of neutrophils, lymphocytes, and plasma cells within the brain parenchyma with an ill-defined central necrotic zone composed of inflammatory cells, cellular debris, and microorganisms. In human literature, cerebritis is used to denote brain parenchymal inflammation secondary to infection with bacteria or other non-viral pathogens. In contrast, encephalitis is typically viral in origin.[32]

Subsequently, the necrotic center increases in size and becomes more well defined. As the abscess becomes more chronic, the central necrotic area regresses and, if the patient survives without treatment, the abscess will heal as a collapsed fibrotic glial scar.[12]

Our study demonstrates a significant correlation between a peripheral hypointense halo on T2W and T2*W GE sequences and brain abscesses. This halo is due to paramagnetic free radicals within phagocytic macrophages and it has already been described in both human and veterinary medicine.[8,13,15,16,19,21,33] However, although seen in most abscesses in our study, this halo was not detected on all abscesses; moreover, it was also visible in the MRI study of one patient with a glioma. A T2W and T2*W GE peripheral hypointense halo has been described in both veterinary and human literature in several conditions such as gliomas, chronic

hematomas, metastases, granulomatous lesions, infarctions, meningiomas, and radiation necrosis.[12,19] Despite its statistical significance, it cannot therefore be regarded as pathognomonic for brain abscesses.

Another MRI finding that statistically correlated with brain abscesses was the presence of an even enhancing capsule. This may be explained by the pathophysiology of brain abscess formation, which includes four different stages: the first two stages represent the "early" and "late cerebritis" phases without collagenous capsule; during stage 3, called "early capsule", there is an initial deposition of collagen at the periphery of the necrotic center and it is followed by ingrowth of granulation tissue and neovascularization; in the fourth or "late capsule" stage there is complete formation of the capsule surrounding the necrotic center.[12] Ring enhancing gliomas are not truly encapsulated, and the peripheral enhancing portion of the lesion represents expanding neoplastic tissue with microvascular proliferations surrounding a central necrotic core.[31] The intrinsic neoplastic nature of this tissue may explain both its uneven peripheral enhancement pattern and the progressive central enhancement noted in 9 out of the 12 T1W delayed postcontrast sequences that correlated with ring-enhancing gliomas. In both veterinary and human literature, intra-axial lesions usually show progressively increased conspicuity on delayed postcontrast sequences.[4,29,34] Moreover, the presence of tumor angiogenesis along with poorly vascularized peripheral neoplastic tissue surrounding the necrotic center may play a role in the delayed central progression of the enhancement.[31]

In one brain abscess a very mild progressive central enhancement was seen. In this case, immediate and delayed postcontrast T1W sequences were acquired in different planes and the progressive central enhancement may therefore not be real. Other possible explanations include a partial volume artifact due to the capsule's thickness or the presence of a very thick capsule that necessitated more time to enhance completely.

When evaluating the ratio between the lesion diameter and the capsule's thickness in the immediate postcontrast T1W sequences, a cut-off >12 (43.75% sensitivity and 85.71% specificity) can be proposed for the detection of ring-enhancing gliomas. The uneven peripheral enhancement pattern of ring-enhancing gliomas due to the presence of microvascular proliferation compared to the more even and smooth capsule of brain abscesses[12,31] would explain why ring-enhancing gliomas had higher lesion diameter:capsule thickness ratio than abscesses.

T2 FLAIR sequences have been proposed to characterize fluid collections and differentiate fluid-cavitary lesions from other parenchymal T2 high signal lesions.[6] Cystic regions are typical of canine glioblastoma but can also occur in approximately one-third of low-grade canine gliomas;[6,31] on the other hand, brain abscesses are associated with a necrotic core during their development which may mimic the signal intensity and the cellular density of a ring-enhancing glioma.[12,31] This may explain the lack of statistical significance of an intralesional T2 FLAIR attenuating component in our study.

The grade of the perilesional vasogenic edema was not statistically significant; vasogenic edema is secondary to the disruption of the blood-brain-barrier (BBB) and represents a nonspecific feature of several brain diseases including neoplastic and infectious disorders.[35,36] In humans, two patterns of vasogenic edema have been described: type 1 is seen in the immediate vicinity of low-grade and nonglial tumors and is thought to be secondary to parenchymal compression with secondary ischemia and necrosis; type 2 occurs with high-grade glial tumors and is characterized by fingerlike projections reflecting tumor microinvasion causing additional derangements of the BBB.[35] Further studies are needed to investigate the relationship between the severity of perilesional vasogenic edema, brain abscesses and low- and high-grade gliomas.

The presence of intralesional T2*W GE susceptibility artifact was observed in 4/13 patients with ring-enhancing gliomas and only in 1/9 with brain abscesses, failing to achieve statistical significance, probably due to the small sample of patients. These susceptibility artifacts were likely consistent with hemorrhage, which is more commonly reported in gliomas.[5-7,31,37] A recent article in veterinary medicine recommends the use of SWI because it allows better definition of intracranial hemorrhage.[37] In the same study, the presence of intra- and extralesional fine, linear, and continuous susceptibility SWI artefacts was identified in 74.1% of intracranial tumors and was interpreted as neovascularization.[37] In our study population, SWI images were only available for a single glioma patient, showing some intralesional foci/tubular susceptibility artifacts that were not visible on the T2*W GE sequence. In the brain abscess group, T2*W GE intralesional susceptibility artifacts were seen in one feline patient. These artifacts were attributed to hemorrhagic foci secondary to the recent bite wound reported in the medical record.

Only seven MRI studies included a DWI/ADC sequence. This sequence was not included as part of the standard MRI brain protocol for many of the institutions. All ring-enhancing glioma patients for whom a DWI/ADC sequence was available (n=6), showed an unrestricted diffusion of the lesion whereas the only patient with a brain abscess showed an abnormal restriction to diffusion. These findings agree with what is reported in human and veterinary medicine[21,23, 33, 38,39] In humans, atypical diffusion (e.g., restriction to diffusion in gliomas and unrestricted diffusion in brain abscess) is reported in 5-21% of the cases. [24-26] In veterinary medicine, restriction to diffusion in glial cell tumors has been described[40] while there are no reports about unrestricted diffusion in brain abscesses.

In humans, the "dual rim sign" in SWI is the most specific imaging feature to distinguish gliomas and abscesses.[20] This sign is typically seen in pyogenic abscesses while it has never been reported in gliomas.[20] In our study, only one patient with glioma had SWI images

available, without evidence of “dual rim sign”. The lack of visualization of “dual rim sign” in this patient agrees with what is reported in human medicine. Unfortunately, due to the retrospective nature of our study, a SWI sequence was not included in the MRI protocol of any patient of the abscess group. Future studies are needed to investigate the utility of the SWI sequence in veterinary medicine.

The major limitation of this study is the use of different MRI equipment and protocols. Low-field MRI might have failed in detecting small lesions. The different planes in some studies between the immediate and the delayed postcontrast T1W sequences might have caused incorrect interpretation of the effective progression of the central enhancement.

Another limitation is that, due to the retrospective and multicenter nature of the study over a long period, different histological classification systems were used from different veterinary pathologists with different backgrounds. For this reason, we decided not to make a distinction between high- and low-grade ring-enhancing gliomas.

A potential source of bias was that the authors were aware of the final diagnosis at the time of image interpretation. However, we did not consider it a major concern because the study aimed to describe the MRI features of brain abscesses and ring-enhancing gliomas and not test the diagnostic accuracy of MRI. In conclusion, even if several overlapping MRI features between ring-enhancing gliomas and brain abscesses do exist, some features can help to prioritize the MRI diagnosis. The presence of a homogeneous T1W or T2W signal intensity, a T2W or T2*W GE peripheral hypointense halo and an even enhancing capsule may indicate a brain abscess. The central progression of the enhancement on delayed postcontrast T1W sequences is indicative of glial neoplasia. The addition of DWI and SWI sequences on high-field MR scanners should be considered for assessment of intra-axial brain lesions which cannot be easily discriminated using standard MRI sequences.

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Category 1

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(b) Acquisition of Data: Andrea Carloni, Swan Specchi, Marco Bernardini, Chiara Mattei, Angela Vittoria De Magistris, Francisco Llabres-Diaz, Jonathan Williams, Rodrigo Gutierrez-Quintana, Anna Oevermann, Daniela Schweizer-Gorgas, Cyrielle Finck, Isabelle Masseau, Valentina Lorenzo, Annalisa Sabatini.

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Table 1: Qualitative MRI features of ring-enhancing gliomas and brain abscesses in dogs and cats.

			Glioma (n = 16)	Abscess (n = 15)
Signal homogeneity	T1W	Homogeneous	4/16 (25%)	10/15 (66%)
		Heterogeneous	12/16 (75%)	5/15 (33%)
	T2W	Homogeneous	0/16 (0%)	5/15 (33%)
		Heterogeneous	16/16 (100%)	10/15 (66%)
Signal intensity	T1W	Hypointense	11/16 (69%)	14/15 (93%)
		Isointense	4/16 (25%)	1/15 (6%)
		Hyperintense	1/16 (6%)	0/15 (0%)
	T2W	Hypointense	0/16 (0%)	3/15 (20%)
		Isointense	0/16 (0%)	1/15 (6%)
		Hyperintense	16/16 (100%)	11/15 (73%)
T2W peripheral hypointense halo	Presence		1/16 (6%)	9/15 (60%)
	Absence		15/16 (93%)	6/15 (40%)
T2*W GE peripheral hypointense halo	Presence		1/13 (8%)	5/9 (55%)
	Absence		12/13 (92%)	4/9 (44%)
T2 FLAIR intralesional attenuating component	Presence		10/16 (62%)	9/15 (60%)
	Absence		6/16 (37%)	6/15 (40%)
T2 FLAIR white matter perilesional edema	Grade 0-1		8/16 (50%)	2/15 (13%)
	Grade 2-3		8/16 (50%)	13/15 (86%)
Pattern of ring-enhancement	Even		1/16 (6%)	10/15 (66%)
	Uneven		15/16 (93%)	5/15 (33%)
Progressive central enhancement on delayed T1W post-contrast	Presence		9/12 (75%)	1/10 (10%)
	Absence		3/12 (25%)	9/10 (90%)
Susceptibility artifacts on T2*W GE~~SWI~~	Presence		4/13 (31%)	1/9 (11%)
	Absence		9/13 (69%)	8/9 (89%)
Signal on DWI/ADC	Unrestricted diffusion		6/6 (100%)	0/1 (0%)
	Decreased diffusion		0/6 (0%)	1/1 (100%)
"Dual rim sign" on SWI	Presence		0/1 (0%)	N/A
	Absence		1/1 (100%)	N/A

491 Table 2: Comparison between MRI findings in ring-enhancing gliomas and brain abscesses in

492 dogs and cats.

	Gliomas N=16	Abscesses N=15	Chi-square test	P	Relative risk	95%CI
T2W homogeneous lesion	0	5	4.13	0.042	2.6	1.6-4.23
T1W homogeneous lesion	4	10	3.87	0.049	2.4	1.08-5.45
Intensity of the lesion on T2W sequences			4.90	0.050		
- **hyper**	16	11	2.81	0.093		
- **iso**	0	1	0.001	0.974		
- **hypo**	0	3	1.62	0.202		
Intensity of the lesion on T1W sequences			3.13	0.251		
- **hyper**	1	0	0.001	0.974		
- **iso**	4	1	0.81	0.369		
- **hypo**	11	14	1.63	0.202		
T2 FLAIR intralesional attenuating component	10	9	0.05	0.821		
T2 FLAIR white matter perilesional edema			5.56	0.162		
- **grade 2-3**	8	13	3.23	0.072		
- **grade 0-1**	8	2	1.63	0.202		
Peripheral T2 hypointense halo	1	9	7.92	0.005	3.15	1.55-6.39
Peripheral T2*W GE hypointense halo	1	5	3.97	0.046	3.33	1.33-8.37
Susceptibility artifacts on T2*W GE sequences	4	1	0.32	0.572		
Even ring-enhancing pattern on T1W + C sequences	1	10	9.85	0.002	3.64	1.66-7.95
Progressive central enhancement on delayed T1W post-contrast	9	1	6.86	0.009	0.13	0.02-0.88

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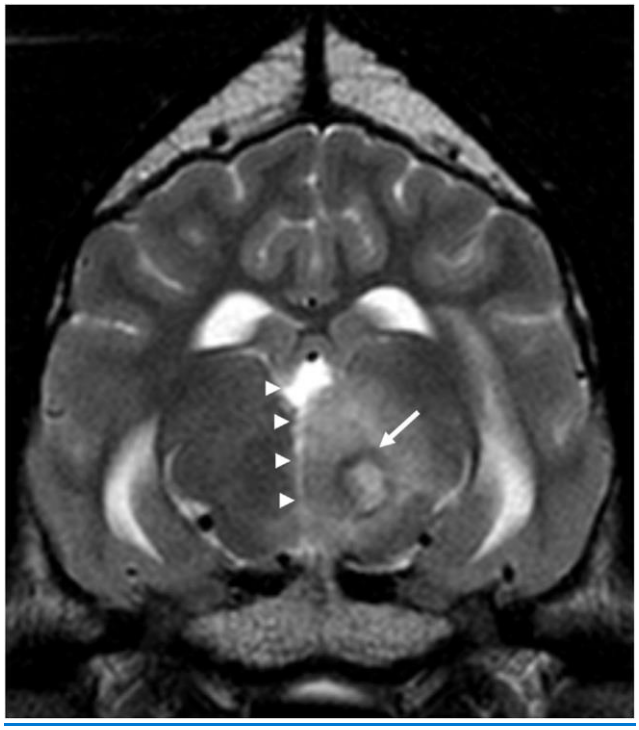

Figure 1: Transverse T2W FSE image (1.5 T, TR 2500, TE 15) of a one-year-old, neutered male, American Staffordshire Terrier with left thalamic abscess. Note the peripheral hypointense halo (arrow) surrounding a homogeneous hyperintense center. There is a moderate mass effect on the third ventricle (arrowheads) along with moderate T2 hyperintense vasogenic edema surrounding the lesion.

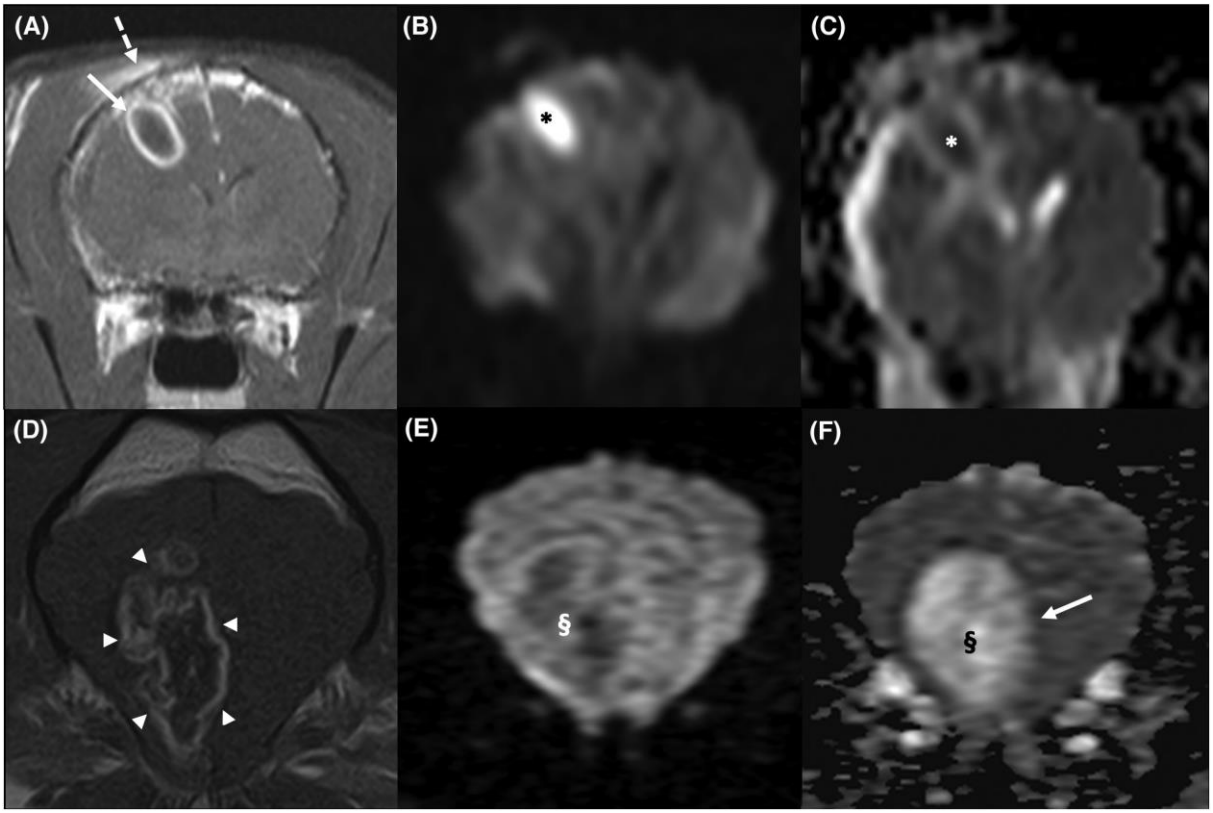

Figure 2: (A-C; 1.5 T, transverse T1W FSE TR 500, TE 13 and transverse DWI/ADC TR 4233, TE 110, B value 1000) 9-year-old, male neutered, DSH cat with a right parietal lobe abscess secondary to a bite wound. An even, well-defined ring-enhancing lesion with hypointense center (arrow) is visible on the T1 post-contrast sequence (A); right temporal myopathy and a calvarial defect are also visible (dashed arrow). On the transverse DWI (B) the central portion of the abscess is strongly hyperintense to normal brain parenchyma (black asterisk) while it shows low values (white asterisk) on the ADC map (C), consistent with restriction to diffusion. (D-F; 1.5 T, transverse T1W FSE TR 465, TE 11 and transverse DWI/ADC TR 4288, TE 94, B value 1000) 5-year-old, male, French Bulldog with ring-enhancing glioma of the right fronto-parietal lobe. The T1W post-contrast sequence shows an unevenly marginated ring-enhancing glioma (arrowheads) (D). On the transverse DWI (E) the central portion of the lesion is hypointense (white §) to normal brain parenchyma while on the ADC map (F) it shows high signal (black §), consistent with unrestricted diffusion.

Note the difference between the even enhancing capsule of the brain abscess (A) compared to the unevenly marginated ring-enhancing glioma (D).

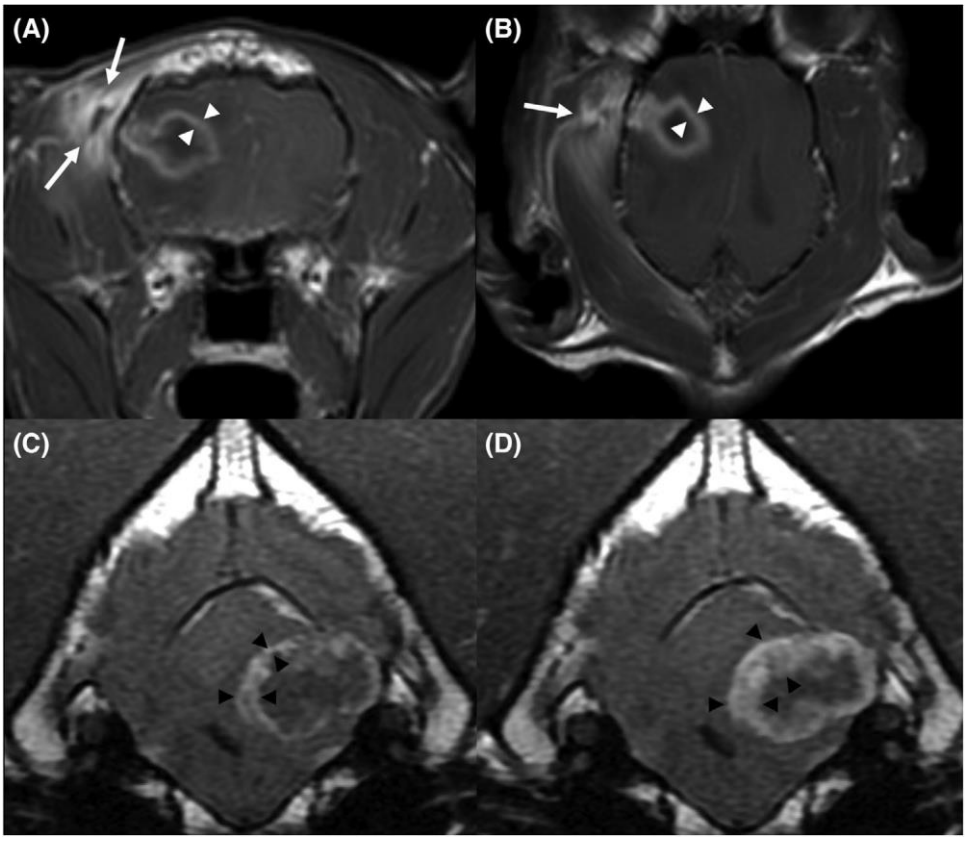

Figure 3: Immediate post-contrast T1W transverse (A) and dorsal delayed post-contrast T1W (B) images (1.5 T, transverse T1W FSE TR 500, TE 13) of a 9-year-old, male neutered, DLH cat with a right temporo-parietal lobe abscess secondary to a bite wound with temporal myopathy (arrows). Despite the different acquisition planes, the thickness of the abscess' capsule does not increase over time (white arrowheads). Immediate post-contrast T1W FLAIR (C) and delayed post-contrast T1W FLAIR (D) transverse images (1.5 T, transverse T1W FLAIR FSE TR 2560, TE 26, TI 1013) of a 9-year-old, female spayed, Labrador Retriever with a left cerebellar ring-enhancing glioma. Note the conspicuous central progression (black arrowheads) of the enhancement on the delayed post-contrast sequence.