MR images for characterizing canine primary brain tumors: a comparison with histopathology

Author: E Wouters, BSc
Supervisor: Dr. SAEB Boroffka
Prof. Dr. G Voorhout

Summary
The MR images and histopathological slides of twenty primary brain tumors (ten meningiomas and ten gliomas) were compared, using defined MR characteristics and the WHO classification. To find a relationship between histological features and MR images the histological slides were compared one-on-one with the MR images for twelve of the tumors.
The aim of this study was to improve the value of MRI for the characterization of primary brain tumors in dogs, using the pathologic findings as feedback. This was done by comparing histopathologic findings and MR images.
This study concluded that neither for meningiomas, nor for gliomas, a distinction between different histological subtypes can be made based on the MR characteristics. Comparing the MR characteristics of meningiomas and gliomas, it can be concluded that it is hard to distinguish them based on these MR characteristics, because both types of tumors show a variety of MR characteristics. For a definite diagnosis, other methods, such as tissue biopsies, are needed.

1. Introduction

Primary brain tumors are the most common brain tumors in dogs, whereas secondary (metastatic) brain tumors occur less frequently (Moore, 1996). According to Snyder et al., the reported incidence of brain tumors in dogs varies. It was estimated between 0,0145 % to 3 % (Snyder, 2006).

For histological classification of tumors of the nervous system the World Health Organization (WHO) has created an international classification system, not only for humans, but also for domestic animals. For the most common primary brain tumors, this classification subdivides nine types of meningioma: meningothelial, fibrous, transitional, psammomatous, angiomatous, papillary, granular cell, myxiod and anaplastic; and three types of astrocytomas: low-, medium- and high-graded and two types of oligodendroglial tumors; oligodendroglioma and malignant (anaplastic) oligodendroglioma (Koestner, 1999).

For diagnosing intracranial lesion MRI is the technique of choice because of its outstanding ability to differentiate soft tissues, due to improved contrast resolution in comparison to CT (Hecht, 2010). When interpreting an MR image several characteristics for brain tumors can be distinguished. The signal intensity, contrast enhancement, mass effect, occurrence of edema and location of the tumor are examples of these characteristics (Van Meervenne, 2005). The appearance of a characteristic or the combination of several characteristics on MR images are used for diagnosing different types of brain tumors.

In a previous review (Wouters, 2010) a table was created in which MR characteristics were plotted against primary brain tumors. Using this table allows one to diagnose the primary brain tumor that is visualized on MR images. For optimizing the use of MRI when diagnosing brain tumors, it might be useful to additionally compare histopathologic findings and the MRI images. The histopathologic findings can be used as a feedback to confirm the diagnostic method. In addition, the knowledge of a histopathologically confirmed tumor can be used to find more or other specific characteristics on MR.

The aim of the present study was to improve the diagnostic value of MRI for differentiating primary brain tumors in dogs, using the pathologic findings as feedback by comparing histopathologic findings and MR images.

2. Materials & Methods

In this retrospective study dogs were selected based on 3 criteria. First a cranial MRI was performed between 2002 and 2010 in the University clinic of companion animals. Second, the tumor or biopsy (necropsy or surgical excision or biopsy) was sent to the pathology department for histopathologic examination. And third, the diagnosis of a primary brain tumor was confirmed.

Histopathology

At the pathology department the brains were examined macroscopically and microscopically. In addition histological slides were made using H&E staining. In three cases complementary staining was necessary for a definite diagnosis (e.g. GFAP). The histological slides were re-examined to determine the type of tumor, based on the WHO classification for tumors of the nervous system in domestic animals (Koestner, 1999). In some cases complementary staining could not be made, therefore these tumors could not be distinguished as astrocytoma or oligodendroglioma, so were called glioma. Pictures were made of the slides for comparison with the MR images.

MRI features

The MR images were performed under full anesthesia with a Siemens MR scanner of 0.2 T.
The animals were positioned in ventral recumbency. Gadolinium-DTPA was used as contrast agent. All used images were transverse unless indicated otherwise. The images were re-examined based on the characteristics signal intensity, contrast enhancement, mass effect, occurrence of edema and location of the tumor.
The signal intensity was graded as hypointense, isointense, hyperintense, relative to cerebral gray matter. The contrast enhancement was described as absent, mild or marked. The post contrast homogeneity was described as uniform or non-uniform. Specific contrast enhancement pattern are “ring enhancement” and “dural tail sign“ and were described as absent or present. Mass effect was graded as absent, mild, moderate or marked. This distinction was made based on whether a shift of the falx cerebri was present or compression of the ventricular system was observed. The presence of edema was determined with the extent of abnormal hyperintensity on T2WI that exceed the area of contrast enhancement on the contrast enhanced T1W image. Cerebral edema was graded as absent, mild, moderate or marked. When graded as mild, edema is present in the area immediately next to the tumor, also referred to as peritumoral edema. When edema was graded as moderate, it extends beyond the area immediately next to the tumor. When graded as marked the entire hemisphere is involved. Location of the tumour within the brain was described as: cerebrum (telencephalon, diencephalon), brainstem (mesencephalon, medulla and pons) or cerebellum.
The axial origin was referred to as intra-axial or extra-axial (Thomas, 1996).

Comparison Histopathology with MR images

The histological classification and MR characteristics of the twenty tumors were compared with each other. In twelve cases histological samples were available containing the transition zone of tumor cells to normal brain tissue allowing a more accurate comparison with the MR characteristics.

3. Results

Twenty dogs were included in this study, ten of which had a meningioma and ten had a glioma.

3.1 Histopathologic findings of the 20 primary brain tumors

Meningiomas
In ten dogs a meningioma was found. Histological examination revealed four subtypes (fig. 1); two meningothelial meningiomas, three psammomatous meningiomas, one angiomatous meningioma and four anaplastic menigiomas.

Gliomas
In ten dogs gliomas were found. Histological examination revealed four astrocytoma, three of which anaplastic and the fourth low-graded, and four oligodendroglioma, three well-differentiated and one poorly differentiated (fig. 2). In the remaining two no further subdivision by type of glioma could be made.

(A) (B)

(C) (D)

Fig 1. (A) Meningothelial meningioma (B) Psammomatous meningioma, containing psammoma bodies (arrow) (C) Angiomatous meningioma, containing different blood-filled cavities (D) Anaplastic meningioma, containing necrosis, haemorrhage, microcysts and focal increased cell density.

(A) (B)

(C) (D)

Fig 2. (A) Astrocytoma, GFAP positive, cytoplasm colors yellow after GFAP staining (B) Astrocytoma, high-grade anaplastic with mitosis (arrow) (C) Oligodendroglioma, classic 'mucinous lakes' (arrows) (D) Oligodendroglioma, proliferation of the blood vessels and classic 'honeycomb' structure, small dark nuclei and no color of the cytoplasm due to an artefact.

3.2 MRI findings of the 20 primary brain tumors

Meningiomas

Two meningiomas were hypointense, four had a mixed hypo- an isointense appearance and three were isointense on T1WI. An atypical hyperintense area within the tumor area with a hypointense nucleus was seen in one of the tumors (fig. 8). In five meningiomas the T2WI showed a hyperintense and in four cases a mixed iso- and hyperintense appearance. In one tumor a hypointense area with a hyperintense area was visible (fig. 8). On PDWI images eight of the tumors were hyperintense, one was isointense and one showed a mixed iso- and hyperintense appearance. Both these tumors, which did not show a hyperintense PDWI, were anaplastic meningiomas. The same tumor which showed a different T1WI and T2WI, showed a different PDWI as well. A hypointense area in the tumor with a hyperintense nucleus was seen.

All tumors showed contrast enhancement on the post contrast T1WI sequence. In seven of the tumors a marked and in three a mild contrast enhancement was visible. Post contrast homogeneity was uniform in six tumors and non-uniform in four tumors. Ring enhancement was found in one tumor (psammomatous (cystic) meningioma (fig 4)). Four meningiomas showed a dural tail sign of which three were anaplastic and one was an angiomatous meningioma.

Mass effect was marked in five cases, moderate in one, and mild in four. No remarkable mass effect was visible due to the rostral location of one tumor. However, on the sagital image it was visible that the ventricle system may have shifted to caudal due to the tumor (fig. 3). Edema was absent in one case, mild, moderate and marked in three cases each. Location was in nine meningiomas in the cerebrum and in one in the cerebellum. Nine meningiomas showed an extra-axial origin and one meningioma an intra-axial origin (fig. 4).

An overview of the MR characteristics of the ten meningiomas is shown in table 1.

MR characteristics	***MR appearance in meningioma***
Signal Intensity	
T1WI	hypo- (2/10) to isointense (3/10) or mixed intensities (5/10)
T2WI	hyperintense (5/10) or mixed intensities (5/10)
PDWI	iso- (8/10) or hyperintense(1/10) or mixed intensities (1/10)
contrast enhancement	mild (3/10) to marked (7/10)
post contrast homogeinity	uniform (6/10) or non-uniform (4/10)
ring enhancement	1 out of 10
mass effect	mild (4/10), moderate (1/10) or marked (5/10)
edema	absent (1/10) mild (3/10), moderate (3/10) or marked (3/10)
location	cerebrum (9/10) or brainstem (1/10)
axial origin	extra-axial (9/10) or intra-axial(1/10)

Table 1. MR characteristics of ten meningiomas

Oligodendroglioma

The signal intensity of the four oligodendrogliomas was very similar. The T1WI was hypointense, the T2WI and the PDWI were hyperintense. All tumors showed contrast enhancement on the post contrast T1WI sequence; a mild enhancement was seen in three and a marked enhancement was seen in one oligodendroglioma. Post contrast homogeneity was non-uniform in all four tumors. Ring enhancement occurred in two tumors. Mass effect was mild and marked in two oligodendrogliomas each. Edema was seen absent, mild, moderate and marked in one tumor each. All oligodendrogliomas were located intra-axial in the cerebrum. In one tumor a hydrocephalus was seen.

Astrocytoma

Signal intensities of the astrocytomas showed more variety than the oligodendrogliomas. The T1WI was in three astrocytomas mixed hypo- and isointense and in one tumor only isointense. The T2WI was mixed iso- and hyperintense in one tumor and hyperintense in three. The PDWI showed the same mixed and hyperintese images as the T2WI. However the tumor which showed a mixed image on T2WI was not the same as the tumor which showed a mixed image on PDWI. Contrast enhancement was absent and mild in one tumor each, and marked in two tumors. The post-contrast homogeneity was non-uniform in all astrocytomas. Ring enhancement occurred in one astrocytoma. Mass effect was marked in three and absent in one astrocytoma. The tumor with no mass effect was located in the cerebellum. Edema was absent in two tumors and moderate and marked in the other two astrocytomas. Three tumors were located in the cerebrum and one tumor in the cerebellum. Three of the astrocytomas were intra-axial and one of them was extra-axial.

Gliomas without subdivision

Two gliomas could not be further subdivided based on histological slides. On T1WI one tumor had a hypointense, and one tumor had a mixed hypo- and isointense appearance. On T2WI both gliomas were hyperintense. PDWI showed one tumor being hyperintense and one being mixed signal intensities. Contrast enhancement was absent in both gliomas and therefore post-contrast homogeneity was uniform. Mass effect and edema were absent both tumors. Both tumors were located in the cerebrum and were intra-axial. An overview of the MR characteristics of the ten gliomas is shown in table 2.

MR characteristics	***MR appearance in Gliomas***
Signal Intensity	
T1WI	hypo (5/10) to isointense (1/10) or mixed intensities (4/10)
T2WI	hyperintense (9/10) or mixed intensities (1/10)
PDWI	hyperintense (8/10) or mixed intensities (2/10)
contrast enhancement	absent(3/10), mild (4/10) or marked (3/10)
post contrast homogeinity	non-uniform (7/10) and uniform (3/10)
ring Enhancement	3 out of 10
mass effect	absent (3/10), mild (2/10) and marked (5/10)
edema	absent (5/10), mild (2/10), moderate (2/10) and marked (1/10)
location	cerebrum (9/10) or cerebellum (1/10)
axial origin	intra- (9/10) or extra-axial (1/10)

Table 2. MR characteristics of the ten gliomas

3.3 Comparison of histopathological including the transition zone and MRI findings in 12 tumors.

Table 3, 4 and 5 show the histopathological description and the MR characteristics of the twelve tumors which were selected for a more detailed comparison. In these twelve cases histological samples were available containing the transition zone of tumor cells to normal brain tissue allowing a more accurate comparison with the MR characteristics.

number	*type of tumor*	*description*	*figure*
1	Psammomatous meningioma	Encapsulated tumor of epitheloid cells in the lobus piriformis, areas with cells arranged in palisades and areas with whorl-like formations containing psammoma bodies. The contralateral lobus piriformis contains compression atrophy and degenerated neurons, swollen and proliferated astrocytes, and focal edema. The meninges close to the tumor show hyperaemia, focal area with polymorphnucleair leucocytes and leukocytosis.	Fig. 3
2	Psammomatous meningioma	Tumor in the falx cerebri, partially surrounded by meninges. Pattern of lobuli (bundles) and whorls sometimes containing psammoma bodies. Cystic formations filled with fibrillair, eosinofilic reticular material. Spindloid cell with eosinofilic cytoplasm, large oval nuclei. Multifocal necrosis.	Fig. 4
3	Psammomatous meningioma	Multilobulair tumor of spindloid cells, arranged in whorlings containing psammoma bodies. Cells have eosinophil cytoplasm, irregular cell boundaries and oval nuclei. Areas with neutrofils and necrosis are seen multifocal in the central area of the tumor.	Fig. 5
4	Anaplastic meningioma	Well demarcated tumor of polygonal to spindloid cells, arranged in whorlings or sheets. Dilatated blood vessels are seen on the edges of the tumor and ingrowth of the tumor into the meninges. Areas of connective tissue are seen inside the tumor.	Fig. 6
5	Anaplastic meningioma	Tumor in the cerebrum, high cellularity, proliferation of pleiomorphic neoplastic cells which a possible meningeal origin. The cells are arranged in sheets, are round to polygonal and containing round, oval or irregular nuclei. Some mitosis and cells with double nuclei. This tumor also contains plasma cells and lymphocytes. Complementary stainings: GFAP: some positive cells, probably not the tumor cells but pre-existent cells. Cytokeratin: positive	Fig. 7
6	Anaplastic meningioma	High cellular infiltrative tumor attached to the meninges. Moderate pleiomorphic cells arranged in lobule separated by connective tissue with round, oval or irregular nuclei. Multifocal cartilage-metaplasia, necrosis, microcysts and some haemorrhage.	Fig. 8
7	Astrocytoma	Tumor composed of pleimorphic cells with round to oval nuclei, sometimes irregular. Multifocal haemorrhage, necrosis, and acute inflammation and cystic formations. Proliferated blood vessels are seen and there is severe pressure atrophy of the surrounding braintissue.	Fig. 9
8	Oligodendro-glioma	Diffuse pattern of small polygonal to round cells with round to oval dark nuclei and bright cytoplasm (‘honeycomb’ pattern) and proliferated blood vessels, mucinous lakes and necrosis. Some anisocytosis, anisokaryosis and mitosis.	Fig. 10
9	Oligodendro-glioma	Poorly demarcated tumor composed of cells arranged in sheets, which are uniform with pale basophilic cytoplasm and round nuclei. Mucinous lakes and proliferated blood vessels inside the tumor. In the surrounding area and meninges, proliferated blood vessels are seen and also some fibrosis and edema. Poorly differentiated tumor. Cells are uniform with pale basophilic cytoplasm and round nuclei.	Fig. 11
10	Oligodendro-glioma	Infiltrative growing tumor. Cell contain dark nuclei and bright cytoplasm (‘honeycomb’ structure) multiple apoptotic cells and some mitosis are seen. Proliferated blood vessels and mucinous lakes are seen inside the tumor. Proliferated blood vessels are seen in the surrounding of the tumor as well.	Fig. 12
11	Glioma	Tumor composed of infiltrating reticular to spindloid cells with oval nuclei and visible nucleoli, multifocal haemorrhage and some necrotic neurons. No proliferated blood vessels visible. In the brainstem around this tumor, perivascular granulomatous inflammation, mild edema and haemorrhage are seen. GFAP negative.	Fig. 13
12	Glioma	Diffuse vacuolar (spongiform) changings in the grey matter of the cerebrum and also in purkinje layer of the cerebellum (Due to Spongiform polio-encephalopathy). Also a tumorous process of gliacells in the cerebellum. A diffuse arrangement of cells. The cells are small, nuclei are dark. Involvement of the meninges.	Fig. 14

Table 3. Histological description

meningiomas	*1*	*2*	*3*	*4*	*5*	*6*
signal intensity						
T1WI	hypointense	mixed intensities, hypo- and isointense	isointense	mixed intensities, hypo- and isointense	isointense	mixed intensities, hypo- and hyperintense
T2WI	hyperintense	mixed intensities, iso- and hyperintense	hyperintense	hyperintense	mixed intensities, iso- and hyperintense	mixed intensities, hypo- and hyperintense
PDWI	hyperintense	hyperintense	hyperintense	hyperintense	hyperintense	mixed intensities, hypo- and hyperintense
contrast enhancement	mild	mild	marked	marked	marked	marked
post contrast homogeinity	uniform	non-uniform	non-uniform	non-uniform	uniform	non-uniform
ring enhancement	absent	present	absent	absent	absent	absent
mass effect	absent	moderate	marked	marked	marked	marked
edema	absent	mild	mild	moderate	marked	marked
location	cerebrum	cerebrum	cerebrum	cerebrum	cerebrum	cerebrum
axial origin	extra-axial	intra-axial	extra-axial	extra-axial	extra-axial	extra-axial
histological subtype	psammomatous	psammomatous	psammomatous	anaplastic	anaplastic	anaplastic

Table 4. MR characteristics of 6 meningiomas

glioma (n=6)	*7*	*8*	*9*	*10*	*11*	*12*
signal intensity						
T1WI	isointense	hypointense	hypointense	mixed intensities, hypo- and isointense	mixed intensities, hypo- and isointense	hypointense
T2WI	hyperintense	hyperintense	hyperintense	hyperintense	hyperintense	hyperintense
PDWI	iso- and hyperintense	hyperintense	hyperintense	hyperintense	mixed intensities, iso- and hyperintense	hyperintense
contrast enhancement	mild	marked	mild	mild	absent	absent
post contrast homogeneity	non-uniform	non-uniform	non-uniform	non-uniform	absent	absent
ring enhancement	absent	present	present	present	absent	absent
mass effect	marked	mild	mild	marked	absent	absent
edema	absent	absent	marked	mild	absent	absent
location	cerebrum	cerebrum	cerebrum	cerebrum	cerebrum	cerebellum
axial origin	intra-axial	intra-axial	intra-axial	intra-axial	intra-axial	intra-axial
histological type	astrocytoma	oligodendroglioma	oligodendroglioma	oligodendroglioma	glioma	glioma

Table 5. MR characteristics of 6 gliomas.

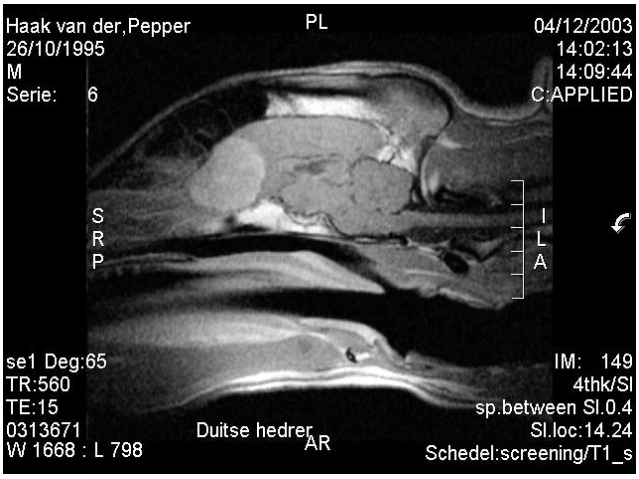

Fig. 3 (tumor 1) Histopathological slide of a psammomatous meningioma and a transversal T1WI post contrast; the tumor is located rostral and the ventricle system is pushed caudally.

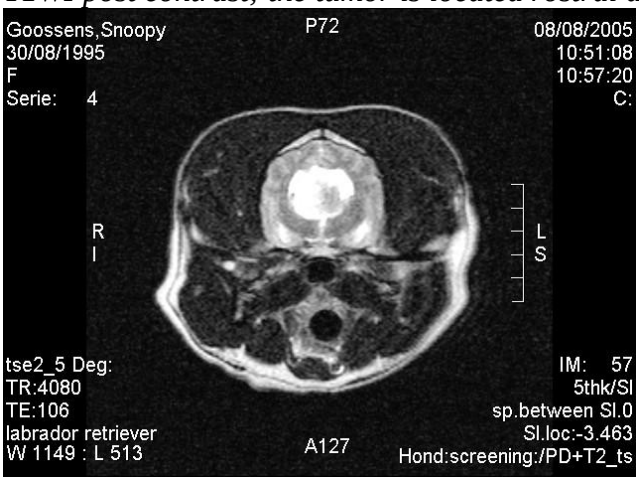

Fig. 4 (tumor 2) Histopathological slide of a psammomatous meningioma with a cystic aspect and a T2WI showing a hyperintense tumor with an isointense area.

Fig. 5 (tumor 3) Histopathological slide shows an area of necrosis within a psammomatous meningioma.

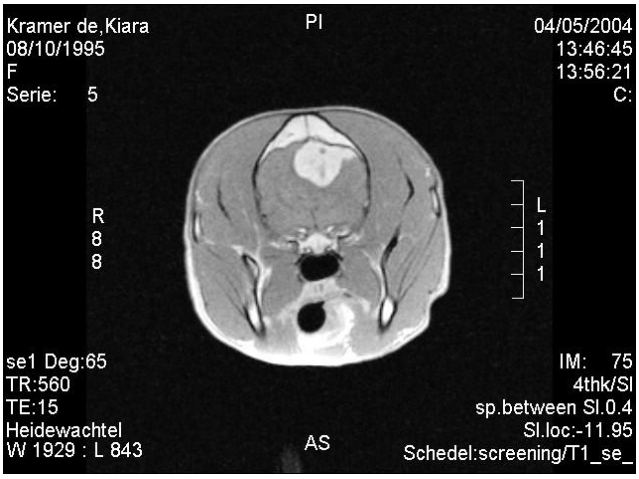

Fig. 6 (tumor 4) Histopathological slide shows a large area of connective tissue (pink) of an anaplastic meningioma. On the T1WI post contrast a dark area can be seen.

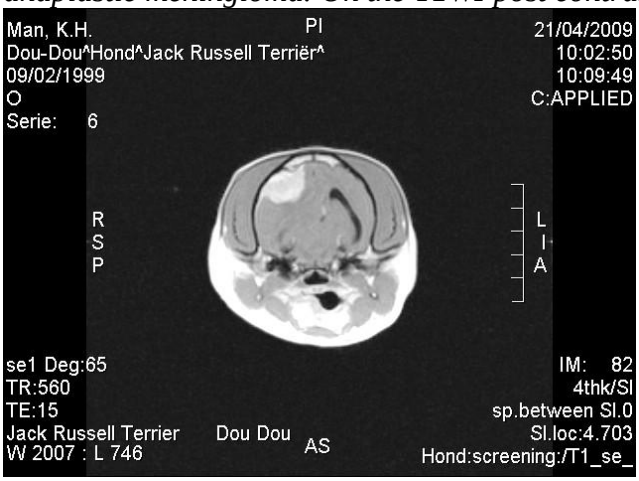

Fig. 7 (tumor 5) The histopathological slide shows haemorrhages on the edge of this anaplastic meningioma. The T1WI post contrast shows a dural tail sign.

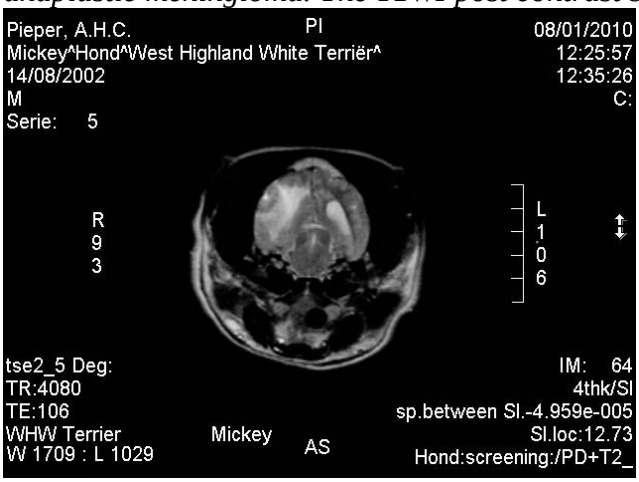

Fig. 8 (tumor 6) The histopathological slide shows an anaplastic meningioma, containing cartilage formation, necrosis, microcyst, high cellularity and haemorrhage. The T2WI shows a hypointense tumor with a hyperintense nucleus and edema in the right hemisphere.

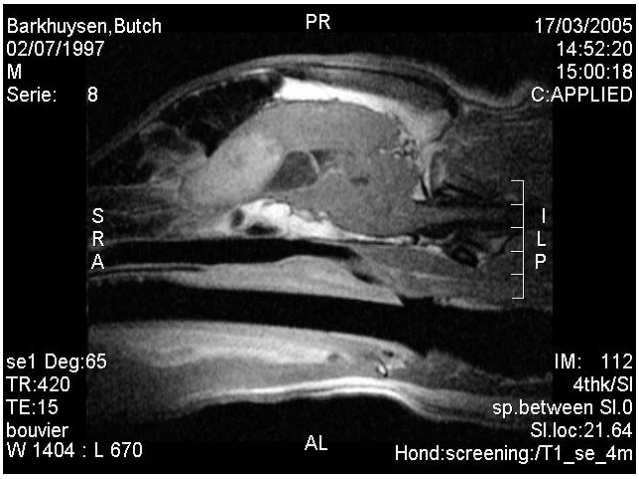

Fig. 9 (tumor 7) The histopathological slide of this astrocytoma shows haemorrhages. The T1WI post contrast shows only little enhancement.

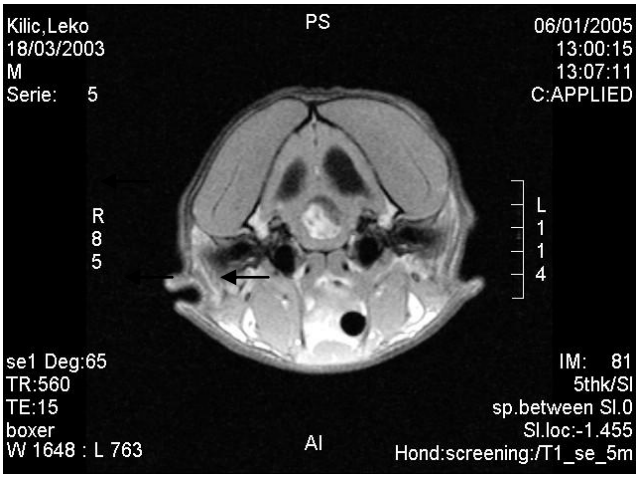

Fig. 10 (tumor 8) The histopathological slides shows proliferated blood vessels (arrows) on the edges of the tumor. The T1WI post contrast shows a ring enhancement.

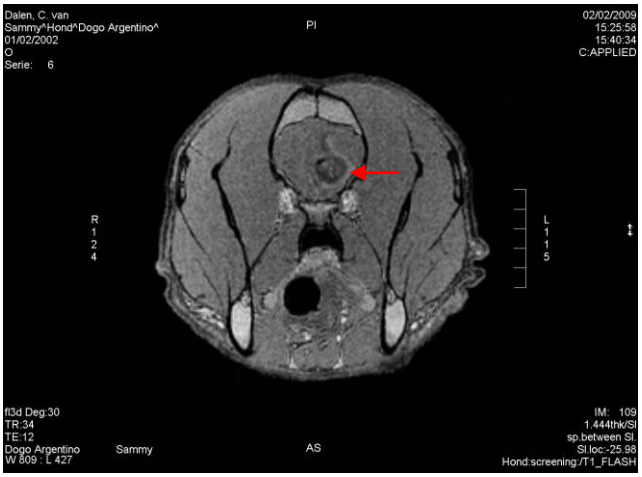

Fig. 11 (tumor 9) The histopathological slide shows proliferated blood vessels in the meninges (left) and hypertrofic meninges. The T1WI post contrast shows very little enhancement (arrow).

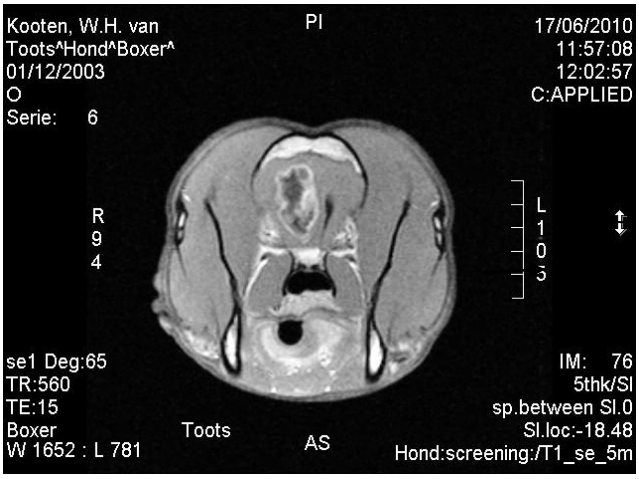

Fig. 12 (tumor 10) The histopathological slide of this oligodendroglioma shows proliferated blood vessels on the edge of the tumor (arrow). The T1WI post contrast shows a very clear ring enhancement.

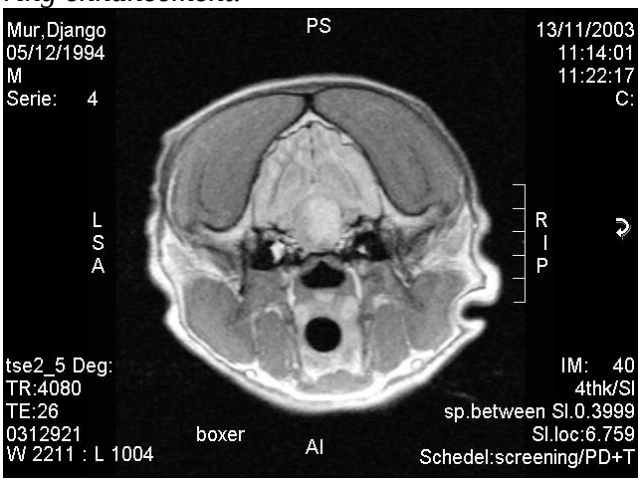

Fig. 13 (tumor 11) The histopathological slide shows the edge of the tumor; the purple cells are tumor cells. The T2WI shows an isointense tumor.

Fig. 14 (tumor 12) The histopathological slide of a glioma in cerebellum; left the normal structure of the cerebellum and right the tumor cells (purple).

4. Discussion

Twenty tumors were described based on their histological subtype and MR characteristics. In twelve tumors histological slides of the transition of tumor tissue to normal brain tissue were available, enabling more detailed comparison with the MR images. This comparison was made in order to examine the existence of a possible relationship between the features seen on the slides and the characteristics seen on the MR image.

Meningiomas

Based on the MR characteristics of meningiomas, no differences of histological subtype could be made, which is in agreement with findings of others (Sturges, 2008).
The mass effect of a rostrally located psammomatous meningioma (tumor 1) was not recognized on transverse images. However, on sagital images the ventricular system appeared to be located more caudally than usual (fig. 3). The T2WI revealed a hyperintense tumor, which did not enhance as bright as expected from a meningioma. This area may contain mineralized tumor cells (psammoma bodies) and therefore the T2WI shows a less bright image.

Another psammomatous meningioma (tumor 2) showed a specific pattern called ring-enhancement on the post-contrast T1WI. An area in the centre of the tumor showed some contrast enhancement as well. The same area had a different signal intensity on T1WI (before contrast) and T2WI. This area may have contained mineralized tumor cells (psammoma bodies) and leading to less signal intensity on the T2WI (fig. 4). Marked for this tumor was the cystic aspect, which also may influence the pattern of signal intensity on the MR images. Cystic meningiomas in humans have a heterogenous structure and mixed signal intensities (Souei Mhiri, 2005). The location of this tumor seemed to be intra-axial, located between the ventricles. According to Gavin et al., the tela choroidea (area where pia mater contacts ependyma) may become neoplastic with meningeal tissue. These tissues are located in the floor of each lateral ventricle and in the roof of the third and fourth ventricle (Gavin, 2009). Therefore, although this meningioma appeared to be intra-axial, the origin was still meningeal.

The histological slides of the third psammomatous meningioma (tumor 3) showed areas of neutrofils and necrosis (fig. 5). Signs of necrosis were not seen on the MR images. The post-contrast T1WI's revealed a uniform enhancement and the T2WI were isointense. T2WI's are expected to be hyperintense when necrosis is present (Sturges, 2008). Also here the isointense T2WI might be explained by the presence of mineralised psammoma bodies.

In one of the anaplastic meningiomas (tumor 4), the post-contrast T1WI showed a marked contrast enhancement, which can be explained by the dilatated blood vessels that were found on the histological slides, except for a small area inside the tumor which did not enhance. On T1WI made fifteen minutes later, the contrast enhancement in the tumor was less than before. However, a small area inside the tumor now revealed bright enhancement. A striking feature seen on the histological slides (fig. 6) was a high amount of connective tissue in one part of the slide. The blood perfusion in connective tissue is low, which may cause a delayed contrast enhancement.

The second anaplastic meningioma (tumor 6) appeared to be quite different compared to the other meningiomas. A hyperintense area on T1WI and hypointense area on T2WI are unusual for meningiomas. Striking features seen on histological slides were the presence of necrosis,

cartilage formations, microcysts and haemorrhage (fig. 8), which may explain the unusual intensities on MR images. Necrosis was found in other tumors as well, but this tumor was the only one with high signal intensity on T1WI. Cartilage is expected to be hyperintense on T2WI (Hodgson, 2011). Microcyst in meningiomas mostly are hypointense on T1WI and hyperintense on T2WI (Paek, 2005). However, if the cysts contain fluid with a high protein concentration, they may be hyperintens on T1WI (http://www.urmc.rochester.edu/smd/rad/neurocases/Neurocase57.htm). The appearance of haemorrhage on MR depends of the stage of breakdown of the blood. In a subacute state (3 days to 1 week), the haemorrhage will be hyperintense on T1WI and hypointense on T2WI when methaemoglobin is present (Elliott, 2010). Other causes of a hyperintense T1WI (in humans) are the presence of mucin, high protein concentration, lipid, cholesterol, calcification of cortical laminar necrosis (http://www.urmc.rochester.edu/smd/rad/neurocases/Neurocase57.htm). None of these features were found on the histological slides, but the slides contain only a small part of the tumor and therefore these causes cannot be excluded. Based on the histological findings, the presence of methaemoglobin is the only explanation for the unusual intensities on the MR images.

Because of the highly anaplastic aspect of tumor 5, histological classification was difficult. Extra stainings (GFAP and Cytokeratin) led to the conclusion that this tumor most likely was a meningioma. Based on the MR characteristics, including the dural tail sign, it is very plausible that this tumor was indeed a meningioma. The dural tail sign is frequently seen in meningiomas, and is rarely reported in gliomas (Guermazi, 2005).

Four out of ten meningiomas in the present study had a dural tail sign on the post-contrast T1WI. This is slightly higher than the 23 to 27% found in other studies (Hathcock,1996; Sturges, 2008).

Gliomas

Based on the MR characteristics, no distinction between the different types of gliomas could be made, which is in agreement with findings of others (Young, 2011). Young et al. found that contrast enhancement was more common in high-graded tumors than in low-grade tumors. In the present study, five out of ten gliomas were poorly differentiated. However, contrast enhancement varied from absent to marked and also within the low-grade tumors contrast enhancement was graded absent to marked. Therefore, in gliomas described in the present study differentiation between high- and low-grade tumors could not be made on basis of MRI.

The astrocytoma (tumor 7) showed mild contrast enhancement on T1WI, while the histological slide revealed clear haemorrhage (fig. 9). When the whole tumor would have contained as much haemorrhage as seen in the slide, a more marked contrast enhancement would have been expected.

In two oligodendrogliomas (tumor 8 and 10), ring enhancement was seen on the post-contrast T1WI (fig. 10 and fig. 12). In the histological slides of both these tumors proliferated blood vessels were seen on the edges of the tumor. In the other two tumors, these proliferated blood vessels were seen as well, but were located more scattered throughout the tumor area and less prominent on the edges. These proliferated blood vessels could explain the ring enhancement on the MR images and the non-uniform post contrast enhancement. The hypointense areas

inside the tumor on T1WI might be explained by the mucinous lakes that were found histologically.

The histological slides of another oligodendroglioma (tumor 9) revealed hypertrofic meninges containing proliferated blood vessels (fig. 11). In spite of this only very little enhancement was seen on post-contrast T1WI. This slide was probably made on the right side of the image (arrow); that is the only part with post–contrast enhancement, and might have contact with the meninges. The low signal intensity on the T1WI might be caused by the presence of mucinous lakes.

Three of the four oligodendrogliomas showed a remarkable contact with the ventricular system. Young et al. also found 14/16 oligodendrogliomas which had contact with the lateral ventricle (Young, 2011). This finding makes it difficult to distinguish this type of tumor from the choroid plexus tumors or ependymomas.

The four oligodendrogliomas found in the present study, had a very similar appearance on the MR images. However, these characteristics are not unique for oligodendrogliomas and do not allow a definitive diagnosis.

No contrast enhancement was seen in the gliomas (tumor 11 and 12), which could be explained by the fact that no proliferated blood vessels were seen on the histological slides (fig. 13 and 14).

Comparing meningiomas and gliomas

Comparing the MR characteristics of meningiomas and gliomas, it appeared difficult to distinguish these tumors because both types of tumors show a variety of MR characteristics. However, a few differences were present. In general, meningiomas are extra-axial, but exceptions occur as seen with an intra-axial meningioma in the present study.

Contrast enhancement was seen in both meningiomas and gliomas. Due to the extra-axial location of meningiomas, and therefore contact with the extra-vascular space where the contrast agent is present, contrast enhancement occurs in all meningiomas. When the blood-brain-barrier is intact, gliomas and other intra-axial lesions do not show contrast enhancement (Graham, 1998). In the present study, three out of the nine intra-axial gliomas (one astrocytoma and two gliomas which could not be subdivided) did not show any contrast enhancement. The two extra-axial gliomas did show a marked contrast enhancement. All gliomas showed a non-uniform post contrast homogeneity. Four of the meningiomas had a non-uniform post contrast homogeneity and five others had a homogeneous contrast enhancement. So when an uniform contrast enhancement is found, the tumor is more likely to be a meningioma.

Ring enhancement was observed in one meningioma and in three gliomas (two oligodendrogliomas and one astrocytoma). However, as concluded by Young et al., ring enhancement is a nonspecific finding common to many intracranial diseases (Young, 2011).

5. Conclusion

Neither for meningiomas, nor for gliomas, a distinction between different histological subtypes can be made on basis of the MR characteristics. In addition, it is hard to distinguish meningiomas from gliomas on basis of the MR characteristics because both types of tumors show a variety of MR characteristics. Some characteristics, or a combination of characteristics, may be suggestive for the type of tumor. However, when a definitive diagnosis is warranted for prognosis and/or treatment, other methods, such as tissue biopsies, are needed.

6. References

Elliott, I. & Skerritt, G.(Eds.). (2010). *Handbook of small animal MRI*. Oxford: Wiley-Blackwell, 3-12, 85-87

Gavin, P. R., Bagley, R. S., (2009) *Practical small animal MRI.* Wiley-Blackwell, 73-81

Graham, J. P., Newell, S. M., Voges, A. K., Roberts, G. D., & Harrison, J. M. (1998). The dural tail sign in the diagnosis of meningiomas. *Veterinary Radiology and Ultrasound, 39*(4), 297-302.

Guermazi, A., Lafitte, F., Miaux, Y., Adem, C., Bonneville, J. ., & Chiras, J. (2005). The dural tail sign - beyond meningioma. *Clinical Radiology, 60*(2), 171-188.

Hathcock, J. T. (1996). Low field magnetic resonance imaging characteristics of cranial vault meningiomas in 13 dogs. *Veterinary Radiology and Ultrasound, 37*(4), 257-263.

Hecht, S., & Adams, W. H. (2010). MRI of brain disease in veterinary patients part 1: Basic principles and congenital brain disorders. *Veterinary Clinics of North America - Small Animal Practice, 40*(1), 21-38.

Hodgson, R. J., (2011) The basic science of MRI. *Orthopaedics and Trauma 25(2),*:119–130

Koestner, A., Bilzer, T., Fatzer, R. (1999) *Histological Classification of Tumors of the Nervous System of Domestic Animals.* American Registry of Pathology,

Moore, M. P., Bagley, R. S., Harrington, M. L., & Gavin, P. R. (1996). Intracranial tumors.*26*(4), 759-777.

Paek, S. H., Kim, S. H., Chang, K. H., Park, C.-K., Kim, J. E., Kim, D. G., Park, S.-H., Jung, H.-W (2005) Microcystic meningiomas: radiological characteristics of 16 cases. *Acta Neurochir 147,* 965–972

Snyder, J. M., Shofer, F. S., Van Winkle, T. J., & Massicotte, C. (2006). Canine intracranial primary neoplasia: 173 cases (1986-2003). *Journal of Veterinary Internal Medicine, 20*(3), 669-675.

Souei Mhiri, M., Ben Rhouma, K., Tlili-Graiess, K., El Ouni Salhi, C., Jemni Gharbi, H., Ben Hnia, I., Krifa, H., Mokni, M. (2005) Magnetic resonance imaging features of cystic meningiomas. J Neuroradiol. 32(1):54-8.

Sturges, B. K., Dickinson, P. J., Bollen, A. W., Koblik, P. D., Kass, P. H., Kortz, G. D., et al. (2008). Magnetic resonance imaging and histological classification of intracranial meningiomas in 112 dogs. *Journal of Veterinary Internal Medicine / American College of Veterinary Internal Medicine, 22*(3), 586-595.

Thomas, W. B., Wheeler, S. J., Kramer, R., & Kornegay, J. N. (1996). Magnetic resonance imaging features of primary brain tumors in dogs. *Veterinary Radiology and Ultrasound, 37*(1), 20-27.

Van Meervenne, S., Van Bree, H., & Van Ham, L. (2005). Diagnosis of brain tumors in dogs and cats: A review of the literature. *Vlaams Diergeneeskundig Tijdschrift, 74*(3), 193-204.

Wouters, E. (2010) Scriptie: Characterizing primary brain tumors in dogs on MRI

Young, B.D., Levine J.M., Porter B.F., Chen-Allen A.V., Rossmeisl J.H., Platt S.R., Kent M., Fosgate G.T., Schatzberg S.J. (2011) Magnetic resonance imaging features of intracranial astrocytomas and oligodendrogliomas in dogs. *Vet Radiol Ultrasound. 52(2)*:132-41

Internet sites:
http://www.urmc.rochester.edu/smd/rad/neurocases/Neurocase57.htm seen on 10-7-2011