Normal canine brain: comparison between magnetic resonance imaging and cross-sectional anatomy

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SUMMARY

The purpose of this study was to compare the normal anatomy and magnetic resonance images of the same canine brain. For that, brains of 7 healthy Beagle dogs were imaged using a 1T MR unit and an IR sequence (T1) and images were compared with the cross-sectional anatomy of the same dog after euthanasia. Among the 11 images giving an excellent correlation with the cross-sectional anatomical analysis, three of them were retained because of their clinical relevance. Relevant anatomical structures were identified using anatomic atlases after repairing the major embryological brain subdivisions. The MR images were characterised by their excellent contrast between the white and grey matters and ventricles and allow the identification of the majority of sulci and gyri but the most of the brainstem nuclei remained difficulty visible. This comparative analysis in Beagle dogs demonstrates that magnetic resonance imaging allows an accurate identification of the main normal brain structures and may useful for improving diagnosis of abnormal structures and lesions.

Keywords: Magnetic resonance imaging, dog, Beagle, brain, neuro-anatomy.

Introduction

The purpose of this study was to compare normal magnetic resonance (MR) images and the normal anatomy of the same canine brain. Magnetic Resonance Imaging is the technique of choice for studying the central nervous system (CNS), revealing normal anatomy as well as pathological changes in tissues, especially in CNS diseases. The superior contrast resolution of the images, particularly those of the brain, combined with its non-invasive nature are the main advantages of this technique.

Clinical canine brain atlases have been produced: in 1989, KRAFT et al. [16] published an anatomic atlas of a dog with neurological disorders, and more recently, in 2008, LEIGH et al. [17] published a clinical atlas without any comparison with the cross-sectional anatomy of the same dog. A recent study showed the precise cranial nerve emergence and skull foramina [7, 8]. Among carnivores the cat and fox have already been studied. The normal and pathological anatomy has been established for the cat and kitten [1, 10, 27]. For the fox, a comparison with the cross-sectional anatomy was carried out [14]. Other species have also been studied, including the horse [6, 7, 21] (brain anatomy and cranial nerve emergence and skull foramina anatomy), camel [2] (brain anatomy) and the pigeon [18] (brain anatomy).

Table I shows a limited review of studies that have used magnetic resonance imaging (MRI); it includes the species and methods used, and indicates whether an anatomical comparison (dissection) was carried out. There is a lack of data for the normal interpretation of magnetic resonance (MR) brain images. For accurate interpretation of MR brain images, the images obtained should be compared with formalinized cross-sectional anatomy, thus confirming structures identified on MR images by dissection. To our knowledge, there is no previously published material describing the MRI anatomy of the dog brain in which the images are compared with the cross-sectional brain anatomy of the same dog. Consequently, the aim of the present study was to simultaneously compare the
MRI and cross-sectional anatomy of brains in dog. Prior to this study, about thirty MR brain images of normal dogs were preliminary compared between them and in addition, about forty normal brains of dogs were examined using cross-sectional anatomy. As the results of the 2 preliminary studies showed no differences in the topographic disposition of the internal brain structures, only 7 dogs were used to compare MRI and anatomy in the current study.

Materials and Methods

The current study was conducted in accordance with French animal welfare regulations and the protocol adhered to the legal requirements of France.

Seven male healthy Beagle dogs (2.0 ± 0.5 years old, weighing 10.4 ± 0.3 kg) from an accredited experimental breed were imaged (in October 2008, Toulouse, France). This breed was chosen because it is often studied in experimental protocols, allowing direct comparisons with other protocols. Physical and neurological examinations before MRI were normal and they were repeated 3 days after image acquisition in order to reduce the possibility of an ongoing but unrecognized neurological disease at the time of imaging. Complete blood count, full chemistry panel, urinalysis and RX imaging before MRI were also normal. On this basis, the dogs were considered as normal. Dogs were on a diet before anaesthesia.

Medetomidin (DomitorND) was intramuscularly given at 35 μg/kg 30 minutes before induction followed by zolazepam and tiletamide (ZoletilND 100) at 5 mg/kg given intravenously. After acquiring the images, atipamezole (AntisedanND), an antagonist, was given intramuscularly at 175 μg/kg. MRI was performed with a 1T superconducting magnet (Siemens®, Rangueil Hospital, Toulouse, France). The dogs were placed in sternal recumbency on the scanning table. A human standard head coil was used. A sagittal localizer series of initial orientation images or « scout » images gave the opportunity to check the positioning and to perform reposition if necessary, and enabled us to orientate transverse plane slices perpendicularly to the soft palate. A total of 153 transversal contiguous 1.3 mm slices was obtained in the rostro-caudal order (corresponding to a coronal plane for humans) from the muzzle to the second cervical vertebra. T1-weighted images were obtained with an IR sequence. The acquisition time for these images was about 30 minutes. The sequence parameters were: Repetition Time (TR) = 9.70, Echo Delay Time (TE) = 4.00 and flip angle = 8.00. Images were reviewed using a DICOM workstation (OsiriX®).

After slaughtering dogs using medetomidin (DomitorND) at 50 μg/kg and ketamine (ClorketamND 1000) at 17.5 mg/kg and mortal bloodletting, the dog’s head was rinsed using 8 litres of 10% formol immediately after the death. The head was sectioned at the atlanto-axial joint and immediately fixed using 10% formol for 8 days. The brain was gently removed from the skull by sectioning the cranial nerves and pituitary gland. Twelve cross-sections were obtained (thickness: from 3 to 10 mm). All sections were stained, photographed (before and after staining)

### Table I: Exhaustive review of studies using MRI in animals.

<table>
<thead>
<tr>
<th>Authors / References</th>
<th>MRI technical parameters1 (Tesla, Coil, Sequence)</th>
<th>Dissection</th>
</tr>
</thead>
<tbody>
<tr>
<td>KRAFT, 1989 [16]</td>
<td>1.5 T - Gadolinium Head and body coils</td>
<td>Not mentioned</td>
</tr>
<tr>
<td>KARKKAINEN, 1991 [12]</td>
<td>0.02 or 0.04 T - T1/T2 Knee and spinal coils</td>
<td>Absent</td>
</tr>
<tr>
<td>YAMADA, 1995 [27]</td>
<td>0.02 T - T1/T2/Spin echo Custom-made coil</td>
<td>Absent</td>
</tr>
<tr>
<td>HUDSON, 1995 [10]</td>
<td>1.5 T - T1 / T2 / Proton density Forearm coil</td>
<td>Other animals</td>
</tr>
<tr>
<td>ROMAGNANO, 1996 [18]</td>
<td>1.5 T - T1 and spin echo or Gadolinium / T2 Knee coil</td>
<td>Same animals</td>
</tr>
<tr>
<td>CHAFFIN, 1997 [6]</td>
<td>0.35 T - T1 and spin echo / T2 / Proton density Forearm coil</td>
<td>Other animals</td>
</tr>
<tr>
<td>SANNA PASSino, 2001 [21]</td>
<td>1.0 T (heads only)</td>
<td>Other animals</td>
</tr>
<tr>
<td>COUTURIER, 2005 [7]</td>
<td>1.5 T - T1 / T2 and Gadolinium Other animals</td>
<td>Other animals</td>
</tr>
<tr>
<td>KASSAB, 2007 [14]</td>
<td>1.5 T – T2 / Spin echo Head coil Other animals</td>
<td>Same animals</td>
</tr>
<tr>
<td>LEIGH, 2008 [17]</td>
<td>1.5 T – T1/T2/TSE head coil Other animals</td>
<td>Other animals</td>
</tr>
</tbody>
</table>

1MRI technical parameters correspond to the magnetic field (B0) used (in Tesla), the coil used and the sequences used (T1 (longitudinal relaxation time), T2 (transverse relaxation time, proton density, Spin Echo and Gadolinium (contrast agent)).

MRI and cross-sectional anatomy of brains in dog. Prior to this study, about thirty MR brain images of normal dogs were preliminary compared between them and in addition, about forty normal brains of dogs were examined using cross-sectional anatomy. As the results of the 2 preliminary studies showed no differences in the topographic disposition of the internal brain structures, only 7 dogs were used to compare MRI and anatomy in the current study.
and stored in a 5% formaldehyde solution for future studies. The stain used was based on three solutions (chlorhydric acid with phenol and copper sulphate – ferric chloride – potassium ferrocyanide) [23]. The main brain anatomic structures in the selected Beagle breed were identified using anatomical texts and previously published atlases [3, 5, 7, 9, 12, 13, 15-17, 19, 24].

Among the 11 MR images offering strong correspondences with anatomical cross-sections, 3 of them were extensively analysed because of their clinical relevance.

**Results**

Three cross-sections and the corresponding MR images are shown in figures 1 to 3. Neopallium and the major embryological subdivisions of the brain (Rhinencephalon, Telencephalon, Diencephalon, Mesencephalon and Metencephalon) are firstly identified for each image and cross-section [25, 26] and all anatomic structures were named according to the Nomina Anatomica Veterinaria [25].

Different structures of the brain were clearly visible on the MR images due to the excellent contrast between the grey matter, white matter and ventricles. On T1-weighted images, the white matter appears white and the grey matter grey, whereas the cerebrospinal fluid appears black. Sulci and gyri (for example, the marginal sulcus and gyrus in Figure 1, the ectomarginal sulcus and middle ectomarginal gyrus in Figure 2 and the caudal suprasylvian sulcus and gyrus in Figure 3) were easily distinguished. However, most brainstem nuclei were difficult to identify unequivocally on the MR images. Indeed, on the first coupe crossing the brain at the rostral line tangent to the interthalamic adhesion (figure 1), the head of the caudate nucleus could not be clearly identified. On the second coupe crossing the brain at the caudal line tangent to the interthalamic adhesion (figure 2), the red nucleus and the thalamic dorsomedial nuclei were not easily repaired and on the third coupe crossing the brain-cerebellum junction (figure 3), the visualization of the raphe nucleus and the pontine nuclei could not be performed. Only large brainstem nuclei were well defined as the rostral nuclei of the thalamus (figure 3) (figure 3) and can be recognized.

Because of the excellent correspondence between the MR images and the anatomical cross-sections due to the easy identification of white and grey matters, ventricles and main sulci and gyri, it was concluded that the dog positioning was quite adequate.

**Discussion**

MRI has some advantages over computed tomography, such as a superior spatial resolution, a good definition of soft tissue (normal and pathological) details and no secondary effects. Indeed, the T1-weighted imaging sequences provide good spatial resolution and better anatomic contrast for identification of the main structures on selected images in the transverse plane. Transverse images were obtained perpendicularly to the soft palate in order to provide a reference for slice orientation, and...
similar images could be easily obtained from other patients. It should be noted that the angle of the transverse slices may deviate slightly from those in other anatomic atlases; therefore, subtle differences may exist between atlases. In this way, harmonization and systematization protocols will be necessary.

Based on comparison with the cross-sectional anatomy of the same dogs, the MR images were labelled in detail. Although the sequences allowed excellent neuro-anatomical correlation and identification of the most clinically relevant brain morphological structures, some anatomical structures, particularly brainstem nuclei (for example, the central grey matter and the raphe nucleus), remained invisible. By contrast, other nuclei, as the rostral nuclei of the thalamus appeared visible, but this may be an artefact because of the partial volume effect. Because noise limits the interpretation of small structures, a higher number of excitations can reduce it without affecting the spatial resolution using a fast sequence such as fast spin echo. This method increases the image resolution in a comparable time to the conventional spin echo using an increased number of excitations and a finer matrix size, thus improving the signal-to-noise ratio and spatial resolution, respectively [20]. These images can be acquired in a shorter time, allowing scan parameters to be optimized without increasing the time. A recent study showed that the images at 7 T provided better delineation of the brain stem and cerebellar structures, which were difficult to unequivocally identify at 1.5 T [11]. However the use of such a higher performing MR unit is actually unrealistic with regards to the current availability of MR units. Moreover, T1 (longitudinal relaxation time) contrast decreases when B0 (magnetic field) increases. For this study, the human standard head coil was used, but a specially designed radio
frequency receiver coil would enable better distinction of anatomical details with a better signal-to-noise ratio in a shorter imaging time [22]. For small dogs, a knee coil can be used.

The above-mentioned sequence (IR and T1-weighted images) was selected from those commonly used to create anatomic atlases. To ensure that there was no brain lesion, T2-weighted images or FLAIR (Fluid-Attenuated Inversion Recovery) images are recommended [4]. Indeed, many lesions were seen on T2-weighted images and no example was found of intracranial abnormalities in T2-weighted images that were not visible in FLAIR images. In a subsequent study, the use of FLAIR images in addition to T2-weighted images resulted in the detection of otherwise occult abnormalities in relatively few patients [4].

It is important to note that the current study was performed on Beagle dogs and not on brachiocephalic dogs in which some anatomical variations in the skull exist [3] that may modify the dog positioning. Nevertheless, apart this restriction in brachiocephalic dogs, the MRI technique applied here enables a correct identification of the main encephalic structures which could be damaged in neurological diseases and may allow a direct diagnostic of brain lesions such as haemorrhagic lesions after a cranial trauma, thalamic nuclei lesion for certain seizures (partial or generalized) and occurrence of abnormal structures like some tumours.

As a conclusion, MRI remains the most widely used technique for studying the CNS because of its good spatial resolution and its superior soft tissue contrast compared to the computed tomography and this study demonstrated that MR images of the normal dog brain provide excellent visualization of many brain structures. By organizing the brain into its embryological subdivisions and comparing images with the cross-sectional anatomy, it is possible to produce a detailed anatomic atlas to assist users for improving the neuro-anatomical analysis of the MR images and more easily detecting abnormal images and the diagnosis of neurological lesions.

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References


