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## Research in Veterinary Science

journal homepage: [www.elsevier.com/locate/rvsc](http://www.elsevier.com/locate/rvsc)Magnetic resonance spectroscopy of the canine brain at 3.0 T and 7.0 T<sup>☆</sup>Paula Martin-Vaquero<sup>a,\*</sup>, Ronaldo C. da Costa<sup>a</sup>, Rita L. Echandi<sup>a,1</sup>, Christina L. Sammet<sup>b,2</sup>, Michael V. Knopp<sup>b</sup>, Steffen Sammet<sup>b,3</sup><sup>a</sup> Department of Veterinary Clinical Sciences, College of Veterinary Medicine, The Ohio State University, 601 Vernon L. Tharp Street, Columbus, OH 43210, USA<sup>b</sup> Department of Radiology, The Ohio State University Medical Center, 370 West 9th Avenue, Columbus, OH 43210, USA

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## ABSTRACT

The purpose of this study was to evaluate the feasibility of proton magnetic resonance spectroscopy (<sup>1</sup>H MRS) to study the concentration of metabolites in the brain of dogs at 3.0 and 7.0 T. Four healthy male beagles were scanned using 3.0 T and 7.0 T human magnetic resonance imaging (MRI) units. The results obtained showed that all dogs had excellent quality spectra for a small (1 cm<sup>3</sup>) and large (8 cm<sup>3</sup>) voxel at 3.0 T, whereas only 2 dogs had high quality spectra at 7.0 T due to insufficient water suppression. <sup>1</sup>H MRS at 3.0 T appears to be a reliable method to study metabolite concentrations in the canine brain. The development of more advanced water suppression techniques is necessary to improve the results at 7.0 T.

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Magnetic resonance spectroscopy (MRS) is a technique that offers the ability to non-invasively measure the chemical composition of the living tissue (Hetherington et al., 2005). In humans, MRS is used for brain imaging to complement the anatomical data provided by conventional magnetic resonance imaging (MRI) and it has been used to study many brain disorders, such as tumors, stroke, neurodegenerative disorders or epileptic syndromes (Hetherington et al., 2005; Dydak and Schär, 2006; Soares and Law, 2009).

The nuclei most commonly used to study the human brain are protons (<sup>1</sup>H), phosphorus (<sup>31</sup>P), and carbon (<sup>13</sup>C) (Hetherington et al., 2005). Proton magnetic resonance spectroscopy (<sup>1</sup>H MRS) is more commonly used because of the higher natural abundance of protons in organic structures and also due to their high magnetic sensitivity when compared to other nuclei (Kang et al., 2009; Soares and Law, 2009). Proton MRS may be obtained with most conventional MRI units over 1.0 T without additional hardware, provided they have the capability of shimming (optimizing field homogeneity) (Soares and Law, 2009).

MRS may be performed using a single-voxel technique (where a spectrum is recorded for a single brain region) or multi-voxel tech-

nique (where data from multiple regions are acquired simultaneously, also known as chemical shift imaging) (Brown et al., 1982; Hetherington et al., 2005). The term voxel refers to the volume of tissue being sampled (Barker and Lin, 2006; Soares and Law, 2009). Rather than images, MRS data are usually presented as line spectra, the area under each peak representing the relative concentration of nuclei detected for a given metabolite (Soares and Law, 2009). The main metabolites analyzed are *N*-acetylaspartate (NAA), choline (Cho), creatine (Cr), glutamate and glutamine (Glx), myo-inositol (ml), and lipids (Lip) (Hetherington et al., 2005; Soares and Law, 2009).

Several comparative studies can be found in the human literature about the use of <sup>1</sup>H MRS at magnetic field strengths ranging from 1.5 to 7.0 T (Dydak and Schär, 2006; Mekle et al., 2009; Tkáč et al., 2009). The advantages of performing MRS at higher field strengths include increased signal-to-noise ratio, improved spectral resolution and improvement in spectral editing schemes (Terpstra et al., 2002; Mekle et al., 2009). A limited number of investigations have applied <sup>1</sup>H MRS to study the canine brain. The majority of these reports consists of canine models of various brain disorders and utilize magnets up to 1.5 T (Barreiro et al., 2006; Kang et al., 2009). Only one recent study documented canine <sup>1</sup>H MRS at 3.0 T (Lee et al., 2010). To the authors' knowledge, no data is currently available about the use of <sup>1</sup>H MRS at 7.0 T in dogs and a comparison of <sup>1</sup>H MRS at 3.0 and 7.0 T to study the canine brain has never been published.

The purpose of this study was to evaluate the feasibility of <sup>1</sup>H MRS to study the brain of healthy dogs at 3.0 and 7.0 T. Our goal was to determine which magnetic field strength would provide the best quality spectra.

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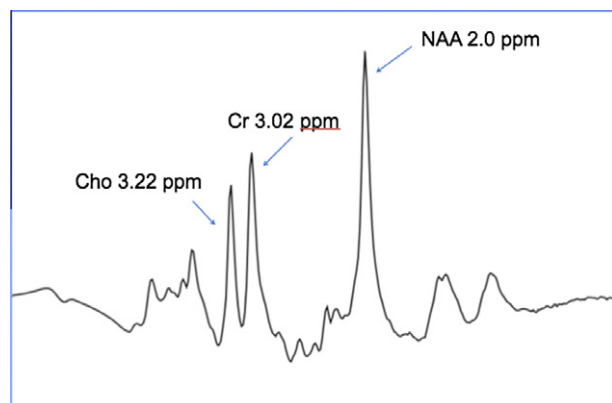
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**Fig. 1.** Spectra obtained at 3.0 T showing the three main metabolites recorded in  $^1\text{H}$  MRS of the canine brain: choline (Cho), creatine (Cr) and *N*-acetylaspartate (NAA); ppm (parts per million).

Four healthy laboratory male Beagle dogs, aged 1.3–3 years and weighing 7.5–12 kg, were studied. All dogs were normal with no evidence of neurologic disease. Results of complete blood counts and serum chemistry profiles were normal. Dogs were premedicated with IM acepromazine maleate (0.15 mg/kg, Vedco, Inc.) and hydromorphone (0.07 mg/kg, Baxter Healthcare Corporation). General anesthesia was induced with IV propofol (4 mg/kg, Diprivan, Astra Zeneca) and maintained with isoflurane (IsoFlo; Abbott Laboratories) using assisted mechanical ventilation. The experimental protocol used for this study was approved by the Ohio State University Institutional Animal Care and Use Committee (IACUC).

MRS studies of all dogs were acquired using 3.0 and 7.0 T human MR scanners (Achieva, Philips Healthcare) under a single anesthetic procedure. An 8-channel receive-only phased-array human knee-coil was used at 3.0 T and a transmit-receive quadrature only knee-coil was used at 7.0 T. The dogs were positioned in sternal recumbency with the head centered in the coil.

A point resolved spectroscopy (PRESS) sequence was used (Terpstra et al., 2002). Two PRESS localized single-voxel spectroscopy acquisitions with  $1\text{ cm}^3$  and  $8\text{ cm}^3$  volumes (samples = 1024; TE = 35 ms; TR = 2000 ms, NSA = 128) were acquired in the canine parietal cortex and cortical-ventricular area, respectively. The spectra were analyzed with the 3DiCSI software (Zhao et al., 2004). Excitation water suppression was optimized and higher order pencil-beam shimming was used to improve the constant magnetic field ( $B_0$ ) homogeneity.

The data were post-processed and interpreted by a physicist. Information regarding NAA, Cho and Cr was recorded for both 3.0 and 7.0 T (Fig. 1). The water line width was determined from unsuppressed water spectra acquired with identical parameters and only linear phase adjustment. Four out of 4 dogs had excellent quality spectra for the small ( $1\text{ cm}^3$ ) and large ( $8\text{ cm}^3$ ) voxel at 3.0 T, while only 2 out of 4 dogs had high quality spectra at 7.0 T.

**Table 1**

Unsuppressed water line width in the MR spectra for different voxel sizes and different magnetic field strengths.

Volume	$1\text{ cm}^3$	$1\text{ cm}^3$	$8\text{ cm}^3$	$8\text{ cm}^3$
	7.0 T (Hz)	3.0 T (Hz)	7.0 T (Hz)	3.0 T (Hz)
Dog 1	17.5	6.9	25.2	7.8
Dog 2	23.9	10.7	21.5	7.8
Dog 3	15.6	7.8	15.6	9.77
Dog 4	13.5	6.85	13.7	7.75
Mean	17.63	8.06	19	8.28
SD	4.49	1.81	5.3	0.99

The mean unsuppressed water line width of the  $1\text{ cm}^3$  voxel was ( $17.6 \pm 4.5$ ) Hz and ( $8.1 \pm 1.8$ ) Hz for the 7.0 and 3.0 T study, respectively (Table 1).

Our study found that MRS in a clinical 3.0 T scanner using an 8-channel phased array extremity coil is an effective method to study the concentration of brain metabolites in the canine brain. However, 7.0 T spectra were only successfully acquired in 2 out of 4 dogs. This was likely due to the insufficient water suppression at 7.0 T, which influenced the quality of the spectra obtained. The radiofrequency field ( $B_1$ ) inhomogeneity of the coil could be responsible for the insufficient water suppression. The 7.0 T water line width was found to be twice the line width at 3.0 T, consistent with results found in human studies (Tkáč et al., 2009), however the standard deviation in the line width was much larger at 7.0 T.

The metabolites recorded in our study included NAA, Cho and Cr. NAA resonates at 2.02 ppm; it is considered as a “neuronal marker” and is invariably decreased in diseases causing neuronal and/or axonal loss, such as brain infarcts. Cho (3.22 ppm) is a metabolic marker of cell membrane density and integrity and it is usually elevated with brain neoplasm, due to increased cellularity. Cr (3.02 ppm) is a marker of “energy metabolism” and it has considerable regional variability (Hetherington et al., 2005; Soares and Law, 2009).

This is the first report presenting the feasibility of  $^1\text{H}$  MRS at 7.0 T to study the canine brain and comparing canine  $^1\text{H}$  MRS data obtained at both 3.0 and 7.0 T. Currently, MRS at 3.0 T appears to be a more reliable option for canine spectroscopy. More advanced water suppression techniques would greatly improve the results of canine MRS at 7.0 T.

#### Conflict of interest statement

None declared.

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