The First in vivo Mouse Proton and Sodium MR Imaging at 21 T

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Introduction

High magnetic fields are expanding our ability to observe and investigate biomedical processes via magnetic resonance. Increased sensitivity, contrast and resolution are especially valuable for many time limited *in vivo* studies. The NHMFL 900 MHz ultra wide bore magnet (900 UWB), with its field of 21.1 T and bore diameter of 105 mm, has opened new opportunities for MR imaging of animals at high field. The first *in vivo* images of a mouse brain acquired on the 900 UWB magnet are presented here. Even for mice, however, this high magnetic field presents challenges in probe design and animal maintenance. These unique high field imaging capabilities were achieved as a result of multiple steps taken to create an *in vivo* experimental setting. The NHMFL is a user facility funded by the National Science Foundation and open to scientists from around the world. Instrument time is granted on an application basis, and all interested researchers are invited to apply.

Materials and Methods

MR imaging experiments were performed with normal mice (C57BL/6J) using a Bruker Avance console operated by PV4.0 and TopSpin 1.5 software. Currently the 900 UWB system is equipped with a Bruker Micro2.5 gradient set and GREAT60 amplifiers. The gradient coil has an internal diameter of 40 mm and a maximum gradient strength of 1.5 T/m. New RF probes were developed specifically for *in vivo* mouse MR proton or sodium imaging at 21.1 T using a single-frequency Alderman-Grant design. The internal diameters and lengths of the RF coils are 17.5 and 25 mm, respectively. Images were acquired for both proton (900 MHz) and sodium (237 MHz) signals. All experiments with animals were conducted according to the protocols approved by The Florida State University ACUC. Image processing was performed using Matlab 7.5 and Analyze 7.0 software.

Results and Discussion

Fifteen coronal images of a mouse head were acquired using a FLASH gradient echo sequence (Fig. 1), TR/TE = 1000/4.3 ms, FOV = 16x16 mm, SW = 50 KHz and matrix = 256x256. The in-plane resolution was 62.5x62.5 µm with a slice thickness of 150 µm. The total accumulation time was ~ 18 min. The resolution of images was sufficient to identify blood vessels in the mouse brain with diameter of ~100 µm, which can be seen throughout the images.

For sodium MRI, a custom-designed 3D back-projection pulse sequence was used with the following parameters: TE = 1.5 ms, matrix = 64x64x64, FOV = 32 mm, SW = 20 kHz, TR = 50 ms, NA = 16. The unique resolution sodium MR imaging of up to 0.5x0.5x0.5 mm was achieved at a total acquisition time of 55 min (Fig. 2).

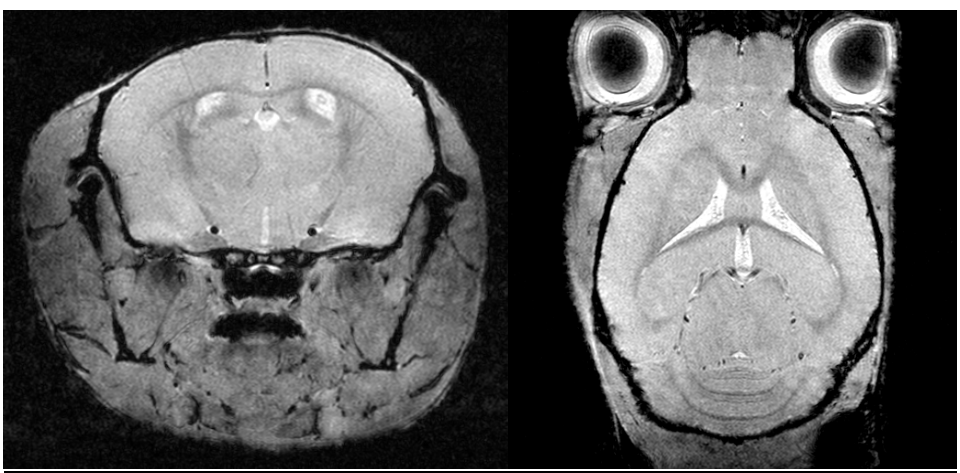

Fig. 1. Proton *in vivo* MR images of a normal mouse at 21.1 T. Resolution is 62.5x62.5x150 µm.

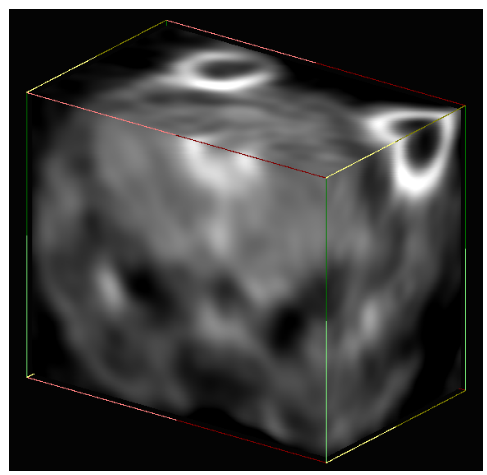

Fig. 2. Sodium i*n vivo* 3D MR image of a normal mouse brain at 21.1 T. Voxel volume is 0.125 µL.

As seen in this image, sodium intensity is high throughout the brain. Some increase in sodium is noticeable at the edges of the brain. The most intense sodium signals can be seen in the ventricular cerebrospinal fluid (CSF) and the eyes. High resolution, *in vivo* sodium MR imaging is an important tool for many future *in vivo* studies.

Conclusion

The first 900 MHz *in vivo* mouse MR images were acquired using the NHMFL 900 UWB magnet system. These novel *in vivo* MR imaging capabilities create new opportunities for users to conduct biomedical research using proton and, especially, non-proton nuclei, where the gain in sensitivity is higher that for proton. The current progress will enable NHMFL users around the country to investigate a host of animal models with the resolution and contrast enhancement afforded by this special instrument.

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