Fluorine-19 Magnetic Resonance at 21.1 Tesla to Detect Brain Inflammation

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Introduction

Neuroinflammation can be monitored with ^{19}F MRI using ^{19}F-nanoparticles (NPs) that label immune cells *in vivo*. The migration of these cells into the brain can then be studied in animal models of multiple sclerosis[1,2]. The low abundance of ^{19}F nuclei *in vivo* poses a major challenge for MR detection in neuroinflammation. The theoretical SNR gain including increases in noise from sample and coil losses is about $SNR \propto B_0^{1.75}$ for solenoidal coils[3]. Recognizing these opportunities and challenges, we investigated the influence of 21.1 T on ^{19}F relaxation times and SNR gain, compared to 9.4 T.

Experimental

Experiments were carried out on the 21.1 T at the NHMFL and a 9.4 T scanner at the Berlin Ultrahigh Field Facility (B.U.F.F.) using similar birdcage coils ($\omega_{(1H/19F)}$ at 21.1 T=900/845 MHz and at 9.4 T=400/376 MHz) and parameters. For relaxation and SNR measurements, tubes of ^{19}F-NPs (perfluoro-15-crown-5-ether)[4] dilutions were submerged in saline. T_1 and T_2 mapping was performed on spin echo sequences using one 10-mm axial slices (FOV=30x30mm) with varying repetition times (TR) or echo times (TE). SNR was calculated on an axial 2D-RARE images (TR/TE=4000/9.1ms, slices=1-10mm). Animal experiments were carried out in accordance with local animal welfare protocols. EAE was induced in SJL/J mice and ^{19}F NPs were administered daily for five days after which mouse tissue was prepared for *ex vivo* MRI. 3D ^{19}F RARE sequence was acquired at low (matrix=90x60x60), medium (matrix=135x90x90) and high (matrix=135x90x90) resolution. A FLASH ^{1}H image was acquired as an anatomical reference to the ^{19}F image.

Results and Discussion

Both T_1 and T_2 values for the ^{19}F NPs were influenced by B_0. The transverse relaxation was decreased at 21.1 T (Fig 1A). T_1 of the ^{19}F NPs decreased by nearly 50% at 21.1 T (Fig 1B), contrary to ^{1}H T_1 relaxation. For SNR measurements, slice thickness was varied and SNR was obtained as a function of the number of ^{19}F atoms per voxel (Fig 1C). An SNR gain of 2.1 was achieved at 21.1 T versus 9.4 T using parameters optimized for 9.4 T. High resolved MRI of EAE mice at 21.1 T revealed a greater level of detail of the immune cell migration in the inflamed brain and draining lymph nodes (Fig 1D).

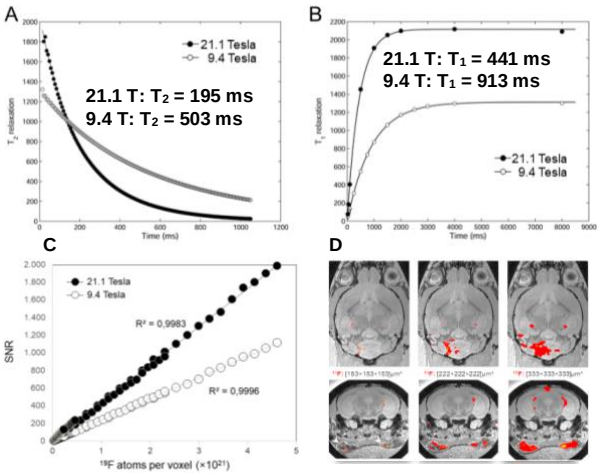

Fig.1A: Signal decay vs. TE yielding T_2. **Fig 2B:** Signal increase vs. TR yielding T_1. **Fig 2B**: Plots of SNR vs. ^{19}F atoms per voxel at the two field strengths. **Fig 2C**: ^{19}F MRI of an *ex vivo* EAE mouse brain acquired at 21.1 T and at different spatial resolutions with FLASH images as anatomical reference.

Conclusions

Our data demonstrate the feasibility of ^{19}F MRI at 21.1 T for detecting inflammation in the brain and adjacent lymphatic system with higher SNR and as a result higher spatial definition. The shortened T_1 is unexpected but consistent with previous studies[5,6]. The difference in the experimental SNR gain (2.1) and the maximum expected SNR gain (2.8) can be explained by coil and receive chain losses as well as preamplifier noise variations between both setups.

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