T_1 relaxation measurements in the mouse brain *n vivo* using Variable Flip Angle - UTE with a cryo-coil at 9.4 T

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Purpose

The inversion recovery ultra short echo time pulse sequence (IR-UTE) and saturation-recovery UTE (SR-UTE) have been showed to be well suited for T_1 and T_2 quantification measurements *in vivo* even for tissues with T_2 shorter than 1 ms [1,2]. However the total acquisition time for both sequences is long often preventing *in vivo* or clinical applications. Furthermore the sequences require high signal-to-noise ratio (SNR) and homogeneous B_1 field produced by an RF coil to ensure proper inversion of the magnetization throughout the sample and sufficient signal. Unfortunately these requirements are in contradiction as the highest SNR can be currently obtained with a surface cryo-coil that generates inhomogeneous B_1 field. We proposed a 3D Variable Flip Angle UTE (3D VFA-UTE) to measure T_1 values for structurally different brain tissues in shorter time than required for IR-UTE or SR-UTE. While 2D VFA-UTE could be also utilized it suffers from the flip angle variability within the slice thus 3D VFA-UTE was used.

Methods

Healthy C57BL/6J mice were investigated using a 9.4T/21cm horizontal bore Bruker Biospec MRI scanner and a Bruker CryoProbe. A set of full 3D images of the brain were obtained using 3D VFA-UTE pulse sequence. The following sequence parameters were used: TR/TE = 10/0.250 ms, FOV = 2 x 2 x 2cm, MTX: 128 x 128 x 128. Two sets of nominal FA values: first one between 0 and 90 deg and second one between 150 and 220 deg were used for T_1 and local FA assessment, respectively.

The average signal intensities for different brain regions representing white matter (WM) (internal capsule-ic), gray matter (GM) (cerebral cortex-CC) and cerebro-spinal fluid (CSF) (left ventricle-LV) were calculated using ImageJ 1.46r software. Two slices were selected at different positions from the cryo-coil surface (Fig. 1).

Due to inhomogeneous RF field produced by the surface cryo-coil the local flip angle varies. Therefore we applied a fitting function to deal with the variability of the flip angle: $y = A*\sin(C*x)*(1-\exp(-TR/T1))/(1-\cos(C*x)*\exp(-TR/T1))$. We introduced a coefficient "C" into the fitted formula to deal with the local variability of the flip angle, which corresponds to mapping of the local B_1 field [3]. This procedure allowed accurate T_1 measurements for each structure.

Results

Application of 3D UTE VFA pulse sequence allowed the accurate quantitative assessment of T_1, resulting in values about 1400 ms, 1700 ms and 2400 ms for WM, GM and CSF, respectively. The fitted C values were > 1 near the cryo-coil surface and < 1 away from the coil's surface, which corresponds to decreasing B_1 (Figs 1 and 2).

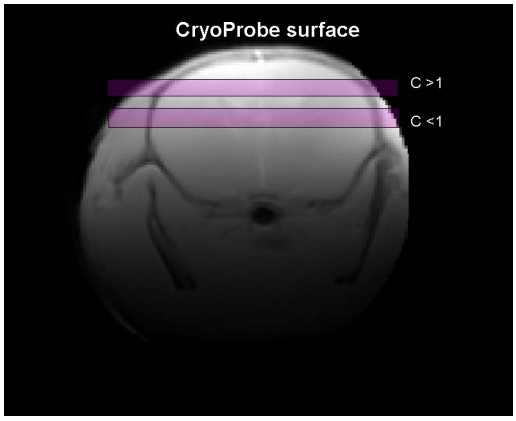

Fig. 1. Axial MR images of the mouse brain *in vivo* using the 3D UTE pulse sequence obtained with the CryoProbe. The bars represent selected slices.

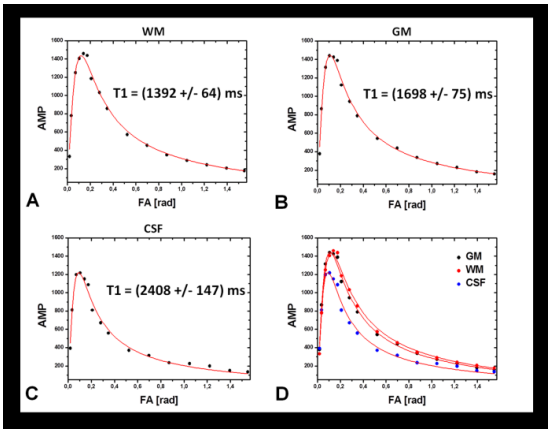

Fig. 2. Plots of the dependence of signal intensity (AMP) on nominal flip angle (FA) for different brain regions used for T_1 evaluation using 3D VFA – UTE: A. WM; B. GM; C. CSF; D. Comparison between WM, GM and CSF.

Conclusions

Utilizing 3D VFA-UTE allows precise T_1 evaluation, making it a suitable method for *in vivo* MRI and possibly for clinical applications. The non-uniform distribution of the local flip angle within the slice can be overcome by mapping the B_1 field using the same pulse sequence.

References

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