High Resolution Arterial Spin Labeling in the Human Brain at 9.4 T – Initial Results using FAIR

Jonas Bause[1,2], G. Shajan[2], Klaus Scheffler[2,3] and Rolf Pohmann[2]
[1] Graduate Training Center of Neuroscience, International Max-Planck Research School, Tuebingen, Germany
[2] Highfield Magnetic Resonance, Max-Planck Institute for Biological Cybernetics, Tuebingen, Germany
[3] Department for Biomedical Magnetic Resonance, University of Tuebingen, Tuebingen, Germany

Introduction:

ASL at ultra-high field benefits from higher SNR and longer longitudinal relaxation times [1]. However, stronger B_1^+ and B_0 field inhomogeneities are challenging for the preparation and readout of FAIR-ASL [2]. We were able to perform the first ASL experiments in the human brain at 9.4T using an optimized adiabatic inversion pulse in combination with a GRE-EPI readout [3].

Material and Methods:

The protocol consisted of a FAIR preparation containing a time resampled FOCI (TR-FOCI) pulse followed by a 2D GRE-EPI readout with minimized temporal spacing between the acquisitions of the different slices. The TR-FOCI was optimized using a genetic algorithm described by Hurley et al. but with modified constraints to benefit from the capabilities of our scanner.

A single subject (male, 28yo.) was measured on a Siemens Magnetom 9.4T scanner with a home-built 16ch transmit / 31ch receive array [4]. The required voltage of the TR-FOCI was estimated based on an actual flip angle (AFI) B_1^+ map. Additionally, the slice profile of the TR-FOCI was determined with an IR-GRE sequence. For the ASL experiment, forty label-control pairs (16 slices, 2x2x2mm^3, no slice gap) were acquired at four different inversion times with flow crusher gradients. M_0 was measured using the same EPI readout but with a longer TR. Image reconstruction and calculations were performed offline in Matlab (MathWorks, USA).

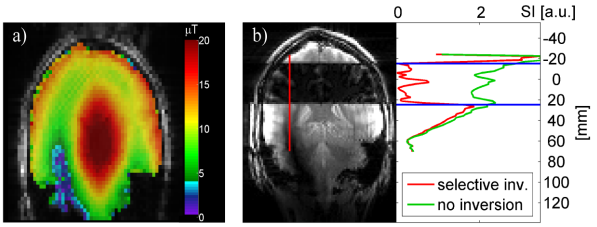

Fig. 1: (a) B_1^+ map (scaled with the voltage of the inversion pulse) of the region where the lowest transmit field strength was measured. Bloch simulation showed that the TR-FOCI pulse used in this study (τ 13 ms, thck. 40 mm) has an inversion inversion efficiency of ≥ 0.99 in 80% of the nominal slice width for B_1^+ levels ≥ 4 µT. This means that an incomplete inversion may have occured in the temporal lobe where the transmit field strength is slightly lower. Imaging parameters: TR1/TR2 20/100 ms, TE 4 ms, FA 60°, 3.2x3x3.2 mm³.
(b) IR-GRE showing the slice profile of the pulse at TI 1000 ms and an example for the corresponding signal along the z-direction. Imaging parameters: TE 1.9 ms, TR 3.8 ms, FA 25°, GRAPPA 3/24, 2.25x1.8x3 mm³.

Results:

Fig. 1a shows the B_1^+ map scaled with the voltage of the inversion pulse. The measured slice profile at the same slice position is depicted in Fig. 1b. Fig. 2 displays the calculated perfusion weighted images for all TIs and every third slice. Note that the three most inferior slices were neglected due to the imperfect inversion slice profile.

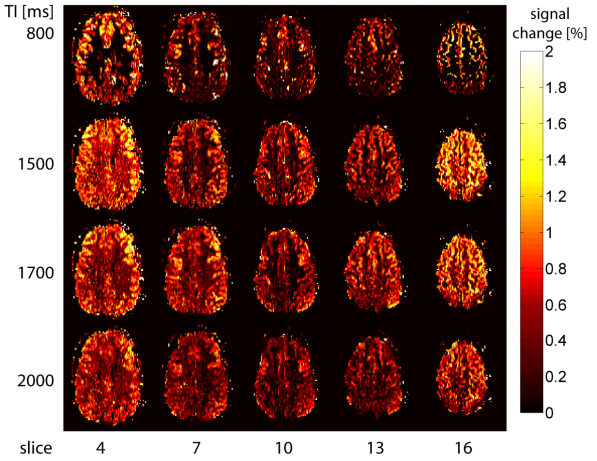

Fig. 2: Perfusion weighted difference images for all measured inversion times (every third slice shown). An increase in gray matter perfusion signal was observed for TI ≤ 1700 ms. However, the signal difference started to decrease again for TI 2000 ms probably due to the reduced bolus width caused by the limited B_1^+ coverage of the transmit array. Imaging parameters: TE 16 ms, TR 5772 ms (7450 ms for M0 measurement), FA 80°, GRAPPA 3/42, 6/8 partial Fourier, 81 % FoV phase FoV, Vcutoff 45 mm/s.

Discussion & Conclusion:

This work shows that FAIR-ASL can be performed at 9.4T with 2mm isotropic resolution. An optimized adiabatic inversion pulse was used for the FAIR preparation in order to improve B_1^+ stability. In a future study, it may be beneficial to replace the non-selective tagging pulse with a spatially confined pulse to reduce the influence of the inferior transmit field variations [5]. For quantitative perfusion mapping with a single subtraction (QUIPSS), a further prolongation of the repetition time may be necessary since the SAR level was already close to the safety limit.

References:

[1] Franke et al., MRI 2000;18(9):1109-1118
[2] Kim, MRM 1995;34(3):293-301
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[4] Shajan et al., MRM 2013;DOI 10.1002/mrm.24726
[5] Zhang et al., JMRI 2005;22(1):119-124