Whole Brain Pulsed Arterial Spin Labelling at Ultra High Field with a B1$^+$-optimised Adiabatic Labelling Pulse

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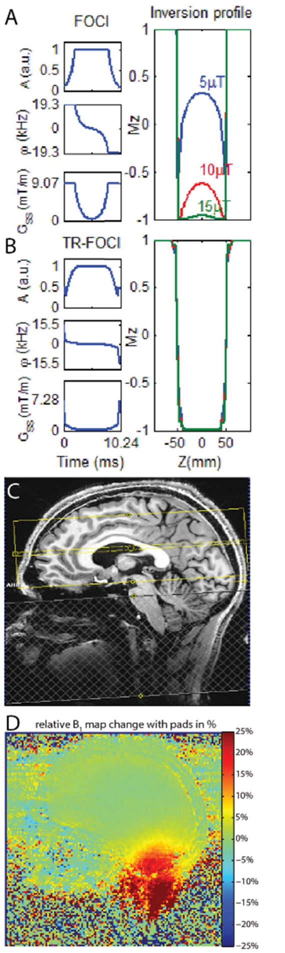

Figure 1 shows the pulse characteristics and inversion profile of the FOCI (A) and TR-FOCI (B) labelling RF pulses, which was placed as shown in C. D shows the relative B_1 changes with pads.

Target Audience: Clinical researchers and neuroscientists interested in whole-brain perfusion at ultra-high field

Purpose: Pulsed Arterial Spin Labelling (PASL) techniques [1,2] should benefit from the increased signal-to-noise ratio and the longer T_1 relaxation times available at ultra-high field. Previous ASL studies [3-5] at 7T have shown promising preliminary results; however, these studies have concentrated on the superior regions of the brain. The underlying reason behind this limitation is that the larger transmit (B_1) radiofrequency (RF) inhomogeneity experienced at ultra-high field presents a challenge to ensure adequate inversion of the blood bolus when labelling in the neck. Recently, various researchers have proposed to overcome this problem with either the use of dielectric pads placed around the neck to enhance the local B1 field [6], or through dedicated transmit labelling coils placed on the neck [7]. Alternatively we propose to utilize a low-power adiabatic pulse [8] designed to cause inversion at much lower peak B_1 and hypothesize that we can provide sufficient blood labelling with no changes to operating conditions and the specific absorption rate (SAR).

Methods: The inversion profile of the frequency-offset-corrected inversion (FOCI) adiabatic RF pulse required to label a 100mm slab of blood is given in Fig. 1A, one can note that it has a large frequency sweep (±19.3kHz) to ensure it overcomes potential ΔB_0 inhomogeneities, but critically it requires a large $B_1 \approx 15\mu T$, to ensure complete inversion occurs. Unfortunately at 7T, the available B_1 in the brain stem/cerebellum can be as low as 4.6-5.7μT [9]. Therefore, in figure 1B, we present an alternative time-resampled (TR) FOCI pulse [7] that makes moderate sacrifices in the frequency sweep (±15.5kHz) and transition bands, to ensure that complete inversion occurs at a target peak B_1 of ≈5μT, Fig. 1B.

<u>Data Acquisition:</u> The effectiveness of the TR-FOCI pulse was tested by replacing the FOCI pulse in a prototype ASL sequence that utilizes the PICORE Q2TIPS [2] labelling scheme. Five volunteers were scanned on a MAGNETOM 7T whole-body scanner (Siemens Healthcare, Germany) with a 32-ch head coil (Nova Medical, Wilmington, US) after giving written informed consent according to the local ethics approval. A total of 4 separate scans were acquired over a 20-minute period. PASL data using either FOCI or TR-FOCI pulses were both acquired with and without dielectric pads placed around the neck as detailed in [6]. The order of the FOCI and TR-FOCI acquisitions were randomized. 30 label-control pairs were acquired with the following sequence parameters: TR/TE 5200ms/15ms, Matrix 64, voxel size 3.3x3.3x3.5mm^3, iPAT 2, BW 1816 Hz/pixel, inversion times TI_1/TI_2 800/2000ms and a saturation stop time of 1800ms. 16 imaging slices were centered on the corpus callosum with the 100mm-thick labelling slab placed 14mm inferior as shown Fig. 1C. Finally, the peak B_1 amplitude of the labelling pulse was chosen to realize the same SAR performance. To show the effect of the pads pre-saturation based sagittal B_1 maps were acquired with and without pads in one volunteer.

<u>Data analysis:</u> All data was processed using MATLAB (The MathWorks, Natick, MA, USA). The 60 control and labelled images were initially realigned and averaged. The gray matter was then segmented with SPM12 (Wellcome Department of Cognitive Neurology, London, UK) on the mean of all images to provide a gray-matter estimate. The perfusion-weighted images were obtained by subtracting the mean control and mean labelled realigned images. The gray-matter mask was then applied to provide the mean and standard deviation values for the perfusion-weighted image. B_1 maps were taken directly from the console and a relative map was calculated.

Results and Discussion: When using dielectric pads, the mean perfusion-weighted signal (a.u) in the gray matter with the FOCI pulse was 6.4±0.5 compared to 8.9±1.9 with the TR-FOCI pulse. Interestingly, without the dielectric pads the mean intensity with the FOCI pulse was 7.0±1.1 versus 8.7±2.4 with the TR-FOCI pulse. Exemplary perfusion images from a volunteer displayed in Fig. 2 show a general increase of the perfusion-weighted signal over the entire brain which is also more homogenous with the TR-FOCI pulse than with the FOCI pulse. The results imply that in contrast to [6] the dielectric pads had little effect on the inversion efficiency of the labelling pulse although Figure 1D shows a B_1 increase of more than 25%, especially in the neck region. But as expected the lower adiabatic threshold required for the TR-FOCI pulse results in a higher perfusion signal. We hypothesize that the effect of the dielectric pads is not that strong in the feeding arteries. Thus, we speculate that the placement of the pads along with the subject's B_1 profile may influence the effectiveness of this approach.

Conclusion: We have shown that pulsed ASL of the whole brain is feasible at ultra-high field without the use of dielectric pads or dedicated hardware.

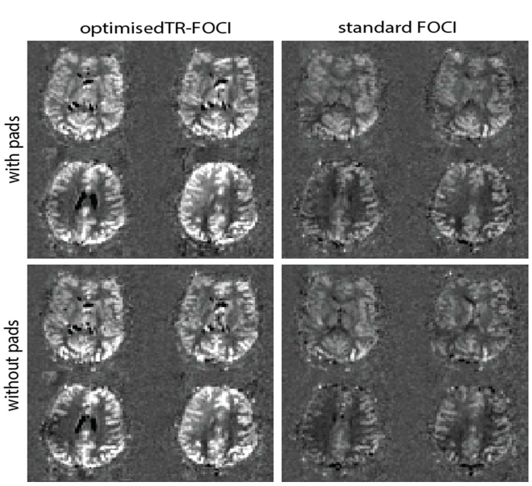

Figure 2 shows exemplary perfusion-weighted images with (top) and without (bottom) dielectric pads when using the TR-FOCI (left) and standard FOCI (right).

Acknowledgements: † both authors contributed equally to the work.

References: **1.** Wong et al.(1997) NMR Biomed 10:237-49, **2.** Luh et al., Magn. Reson. Med. 41:1246-1254 (1999) **3.** Luh et al. MRM 2013. **4.** Zuo et al. PlosOne 2013. **5.** Ghariq et al. Magn Reson Mater Phy. 2012. **6.** Li et al (2014) Proc 22nd ISMRM #955 **7.** Adriany et al (2014) Proc 22nd ISMRM #317 **8.** Hurley A. 63(2010):51MRM **9.** O'Brien et al (2014) JMRI 40(4):804-12