Territorial Arterial Spin Labelling at 7T using PICORE

R. S. Dewey[1,2], D. P. Auer[1], and S. T. Francis[3]
[1]Division of Academic Radiology, The Univeristy of Nottingham, Nottingham, United Kingdom, [2]Sir Peter Mansfield Magnetic Resonance Centre, The University of Nottingham, Nottingham, United Kingdom, [3]Sir Peter Mansfield Magnetic Resonance Centre, The Univeristy of Nottingham, Nottingham, United Kingdom

Introduction: At 3T, Territorial Arterial Spin Labelling (TASL) has been shown to provide a method of selectively labelling individual cerebral arteries allowing maps of their perfusion territories to be derived; territories associated with the internal carotid arteries (LICA/RICA) and basilar artery (BA) are typically mapped [1]. Territory maps provide unique information, for example for the management of steno-occlusive carotid disease [2], or to map the blood supply to arteriovenous malformations where cerebral haemodynamics are altered [3]. Ultra-high field (7T) provides increased image SNR and longitudinal relaxation times increase, theoretically increasing the perfusion weighted contrast [4] and allowing data to be collected at higher spatial resolution. However, at 7T, a head volume transmit coil is used rather than the body transmit coil that is used at 3T. This can result in limited coil coverage of the neck for labelling and inhomogeneities in the B_1 field may limit the labelling region, thus the feasibility of TASL must be assessed. TASL requires high labelling efficiency and sharp inversion profiles to selectively label arteries. Typically a STAR (Signal Targeting with Alternating Radio frequency) scheme is used, and to match magnetisation transfer effects a nominal 360° flip angle is used for the adiabatic tag, and two 180° adiabatic pulses for the control condition [5], thus increasing SAR. Here we test the feasibility of TASL at 7T, implementing PICORE (Proximal Inversion with a Control for Off-Resonance Effects [6]) based TASL to overcome SAR and B_1 limitations.

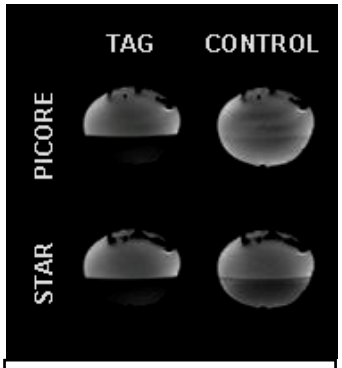

Figure 1: Axial slice (level of cerebellum) through agar-doped phantom showing PICORE and STAR tag and control profiles. Images acquired at phantom null.

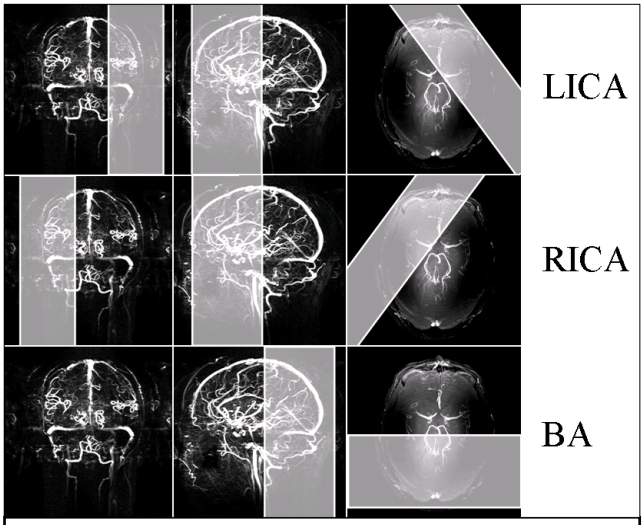

Figure 2: Selective labelling slabs for L/R ICA and BA shown overlaid on PCA and TOF images acquired at 7T. The sagittal PCA highlights the coverage of the volume head transmit coil.

Methods: Sequence optimisation: STAR and PICORE pulsed labelling schemes were assessed for efficiency of labelling using a spherical, agar gel gadolinium doped phantom. For an inferior axial slice through the phantom (plane equivalent to level of cerebellum) labelling efficiency and inversion profile (at the phantom null point ~ 1.2 s) was assessed for an optimised C-FOCI pulse (length = 13 ms, μ = 7.75; β = 4.33, and G_{max} = 4.42). Figure 1 shows the profile of the tag and efficiency of the control for PICORE and STAR. STAR had significantly ($P < 0.001$) reduced label efficiency (α) compared to PICORE (α ~94 % PICORE / α ~77 % STAR, ROI analysis) due to the poor control condition (two 180° adiabatic pulses). In addition STAR increased SAR limiting the number of slices acquired. PICORE was therefore used for the *in-vivo* TASL study.
Data Acquisition: This study was approved by the local ethics committee. Healthy subjects were scanned on a Philips 7.0T Achieva MRI system and all subjects gave written, informed consent. An image-based shimming technique was first used to correct field inhomogeneities and minimize geometric distortions. Coronal and sagittal phase contrast angiograms (PCA) and a time of flight (TOF) MRA were collected to plan the TASL (Figure 2). PCAs had an in-plane resolution of 0.72 x 1.2 mm, TE = 7.6ms, 30° flip angle, phase contrast velocity of 30 cm/s, SENSE factor 2 and comprised two 50 mm slices to visualize anterior and posterior feeding arteries (coronal) and left and right ICAs (sagittal). The TOF was performed using TR/TE = 41/3.5 ms, 20° flip angle, SENSE factor 1.5, in plane resolution of 0.62mm and 240 x 240 x 54 FOV. From this, a maximum intensity projection was formed (MIP), Figure 2. TASL data were acquired using a PICORE scheme with a C-FOCI labelling pulse, described above. In-plane WET pre- and post-saturation pulses were applied over the image volume to suppress static signal (additional thickness 45 mm superior, 10 mm inferior). Background suppression pulses were applied (TI1 = 402 ms, TI2 = 639 ms) and a post-label delay (TI) of 1550 ms, with a TR per label/control pair of 6000 ms. Selective inversion slabs were positioned to label LICA, RICA, and BA [1]. 50 pairs of images were acquired per territory and the acquisition for each territory lasted ~ 4 minutes. The image volume covered ten slices of the cerebral cortex, with a 212 x 191 FOV and 3 x 3 x 5 mm resolution. Figure 3 illustrates the sharp inversion profile of the C-FOCI pulse for each of the three labelling positions. TASL tag and control images were subtracted and averaged to form perfusion weighted difference images providing maps of vascular territories (RICA, LICA and BA).

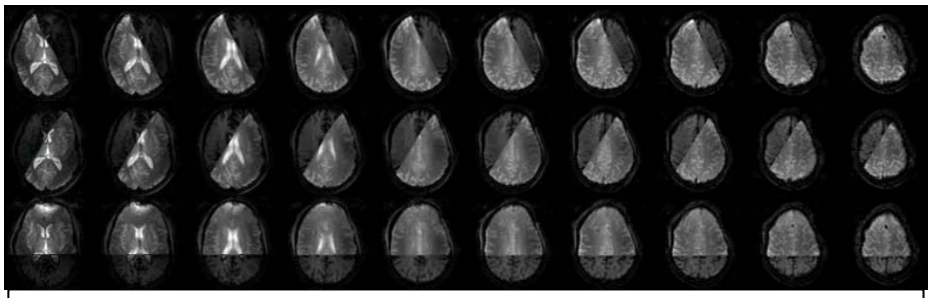

Figure 3: Profile of label shown on slices from the imaging volume for each of the three territories (top, middle and bottom rows: LICA, RICA and BA respectively).

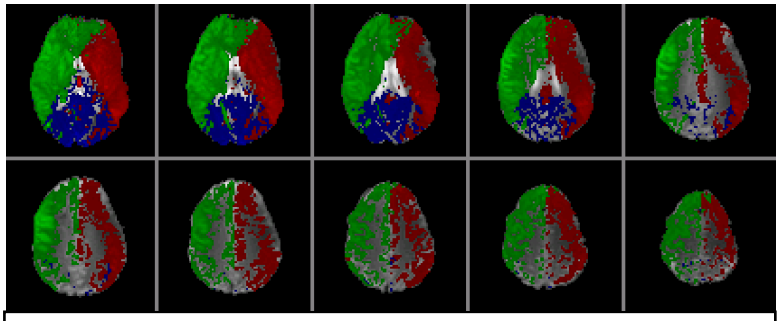

Figure 4: Vascular territories in a healthy human subject at 7T. RICA is shown in green, LICA in red and BA in blue.

Results: Figure 4 shows the vascular territories for the left and right ICAs and the posterior circulation (basilar and vertebral arteries). Clear differentiation of each of the territories is seen.

Conclusions: Using a PICORE labelling scheme it is possible to perform Territorial Arterial Spin Labelling at 7T to selectively label the LICA, RICA and BA. Future studies will implement these techniques to study patients with cerebrovascular impairment.

References: [1] Hendrikse, Stroke, 35; 882-887, 2004. [2] Chng, Stroke, 39; 3248-3254, 2008. [3] Fiehler, Am J Neuroradiol, 30; 356-361, 2009. [4] Gardener, Magn Reson Med, 61; 874-882, 2009. [5] Edelman, MRM, 40; 800-805, 1998. [6] Wong, NMR Biomed, 10; 237-249, 1997.