

Time efficient determination of spin compartments by Time Encoded Arterial Spin Labeling

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Targeted audience: Researchers and clinicians interested in new developments in ASL and compartmentalization of spins.

Purpose: Distinction between ASL-label in vessel and tissue compartments is of special interest, because it provides information on the water transport over the blood brain barrier and helps in quantification of CBF. Previously Liu et al [1] showed by multi-timepoint pseudo Continuous Arterial Spin Labeling (pCASL) acquisitions (labeling duration 1650 ms) the feasibility of compartment determination based on T_2 measurements. However, for use in clinical studies the acquisition time should be shortened and the method could be improved since a shorter bolus duration will be more sensitive to the compartment transitions. The aim of this study is to employ Time encoded (also known as Hadamard encoded) pCASL (te-pCASL) [2] in combination with T_2 -Relaxation-Under-Spin-Tagging (TRUST) [3] to distinguish spin compartments based on their T_2 in a highly time-efficient manner, also enabling voxelwise mapping, while still keeping an equal SNR compared to separate multi-timepoint pCASL scans [4].

Methods: Six healthy volunteers (age 19-29 y, 4 female, 2 male) were scanned at 3T (Achieva, Philips Healthcare) with a 32-channel head coil. For te-pCASL, an 8 x 7 encoding scheme was chosen comprising 8 encoding patterns, each dividing the labeling train into 7 blocks of 400 ms. General te-pCASL protocol: total label duration 2800 ms, post labeling delay (PLD) 325 ms, imaging module with single shot FFE-EPI, 3.2x3.2x7 mm voxel size, 7 slices and TR/TE/fa=3264/16/90°. The T_2 -preparation module was performed with 0, 4, 8, and 16 composite pulses at four effective echo times (eTE): 0, 40, 80 and 160 ms. The signs of the 180° pulses were arranged in an MLEV pattern. For scans with and without vascular crushing ($V_C=5\text{cm/s}$) 96 acquisitions (12 sets of 8 encodings) and 80 acquisitions (10 sets of 8 encodings) were acquired in a total scan time of 18:25 and 22:19 min respectively. Background suppression was applied with FOCI pulses at 1450 and 2560 ms [5]. A Regional Perfusion Imaging (RPI) scan was performed to determine the 3 major flow territories (left ICA, right ICA and posterior) and to create a grey matter (GM) mask. All scans were motion corrected with FSL (FMRIB, Oxford). By subtraction according to the concurrent Hadamard scheme the ASL signal was calculated for the different eTEs and PLDs. The difference between the crushed and non-crushed signal reflects the arterial signal. For each PLD the T_2 -value was calculated over the average GM signal of each region with a monoexponential fit. In addition, a voxelwise T_2 -map was calculated.

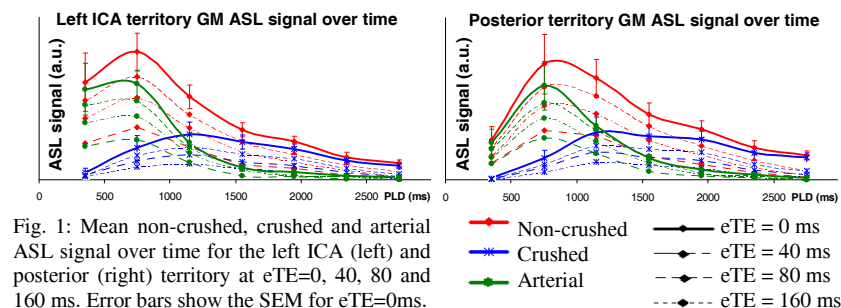


Fig. 1: Mean non-crushed, crushed and arterial ASL signal over time for the left ICA (left) and posterior (right) territory at eTE=0, 40, 80 and 160 ms. Error bars show the SEM for eTE=0ms.

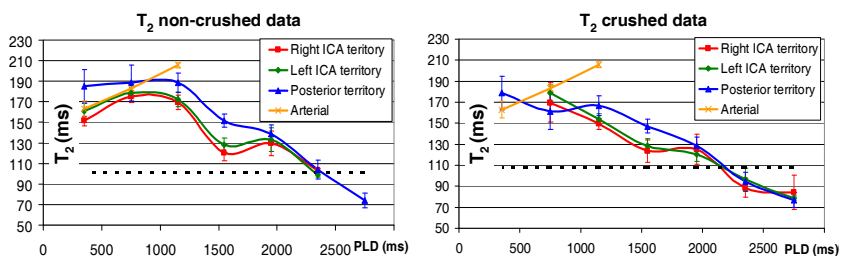


Fig. 2: T_2 values (mean±SEM) of the 3 flow territories for the vascular crushed (left) and non-crushed data (right). Dashed line is the T_2 of the control signal.

Results and discussion: The average ASL signal in the left ICA and posterior flow territories at the different PLDs for the four eTEs is shown in figure 1. The average ASL signal of the right ICA flow territory is similar to the left ICA. At first the non-crushed ASL signal increases in the arteries and between 1150 and 1550 ms the maximum crushed ASL signal is observed in the GM tissue. The label arrives slightly later in the posterior flow territories. The average signal intensity decreases at the longer eTEs due to the T_2 relaxation and at the longer PLDs due to T_1 relaxation. For both the crushed and non-crushed data the change in T_2 -values over time for the different flow territories is shown in figure 2. For some PLDs the signals, mainly arterial, were too low to get a good T_2 fit and are therefore not displayed. For the first 3 PLDs the average T_2 in GM was 170.9 ms for the non-crushed data and 164.3 ms for the crushed data, which indicates that the spins are mainly in the arteries. Between 1550 and 1950 ms the average T_2 in GM reaches a plateau 133.3 and 128.3 ms. This is higher than the expected T_2 -value for tissue, but could be due to including the borderzones into the ROIs. After 1950 ms there is a sharp decay in T_2 to 92.0 and 83.5 ms, which suggest that the labeled spins are completely in the tissue compartment and even transitioning to the venous compartment. In figure 3 the ASL- and T_2 -maps (3 slices) from a single volunteer at different PLDs are shown; note the delayed decrease in T_2 in the posterior territory and in the borderzones.

Conclusion The use of te-pCASL combined with TRUST gives a highly time-efficient way to calculate the T_2 , and distinguish the location of the spins between the arterial and GM tissue compartments.

References 1.P. Liu, *MRM*, 2011, 2 M. Günther, *ISMRM* 2007; 3. H. Lu et al, *MRM* 2008; 4. Dai et al, *MRM*, 2011; 5. Dai et al., *MRM*, 2012

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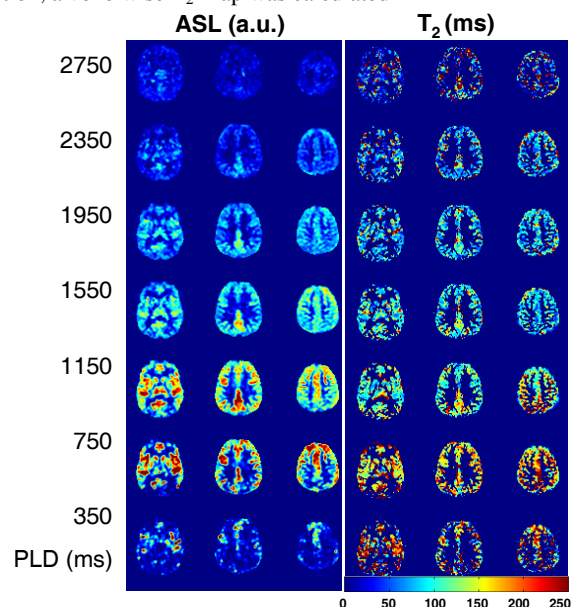


Fig. 3: Three slices of the crushed ASL-maps (left) and grey matter masked T_2 -maps (right) from a single volunteer for different PLDs.