Comparison of spin dynamics in pseudo-continuous and velocity-selective arterial spin labeling with and without vascular crushing

W. M. Teeuwisse[1], A. J. Nederveen[2,3], E. Ghariq[1], D. F. Heijtel[2,3], and M. J. van Osch[1]
[1]Radiology, C.J. Gorter Center for high field MRI, Leiden University Medical Center, Leiden, Netherlands, [2]Radiology, Amsterdam Medical Center, Amsterdam, Netherlands, [3]Spinoza Center, Amsterdam, Netherlands

Introduction: Understanding the dynamics of labeled spins in arterial spin labeling (ASL) is crucial for absolute quantification and correct interpretation of ASL-maps. In particular, it is necessary to estimate the time it takes for label to flow into the microvasculature and exchange with the tissue magnetization. It has been shown previously, that differentiation of spin compartments can be achieved by measuring the transverse relaxation of the ASL-signal at different delay times of the readout [1]. In this study, this approach is adopted to study two important questions: 1) Is vascular crushing necessary to limit ASL-measurements to the perfusion-signal? 2) Does velocity selective ASL exhibit a shorter transport time, because it labels the spins within the imaging slice?

Methods: Five normal volunteers (age 23-51 years) were scanned at a 3T scanner (Philips) using a 32ch head-coil. Four multi-echo scans with Look-Locker sampling strategy were made at a 3.4x3.4x7 mm^3 resolution, flip angle 20°, each lasting approx. 12 minutes: pseudo-CASL with and without vascular crushing (1650 ms labeling, delay times 100, 300, …, 3300ms, saturation preceding labeling, TR = 5200 ms) and velocity selective labeling with and without crushing (v_c = 1.5 cm/s, delay times 100, 300, ..., 2600 ms, TR = 5 s, saturation after last read-out). Five echoes were acquired (TE_{crush} = 14, 27, 40, 53, 66 ms; $TE_{no\ crush}$ = 6, 18, 30, 42, 54 ms). Crushing was performed with v_{enc} of 5 cm/s along all gradient axes at the same time (double oblique). Based on all 4 scans an average CBF-weighted scan was generated for each subject, which was thresholded to obtain a gray matter mask. For each scan and delay time, the average ASL signal over the mask was fitted to a mono-exponential resulting in a T_2^*-estimate and the ASL signal at TE=0ms. The same procedure was applied after subtracting the crushed from the non-crushed ASL-data, resulting in the vascular signal [2].

Results: Figure 1 shows the data from a single volunteer. It can be clearly seen that even at the longest echo and delay time, enough perfusion signal can be detected. Figure 2 shows the signal intensities and T_2^*-values as a function of readout delay.

Discussion and conclusions: Vascular crushing is effective in eliminating vascular signal, while leaving the perfusion signal unaffected. This is demonstrated by a large difference between crushed and non-crushed ASL-signal at short readout delays and no difference between crushed and non-crushed ASL signal for delay times larger than 1800 ms. The passage from the arterial component towards the tissue/microvascular component is easily appreciated in Fig. 2b for PCASL demonstrated by a decrease in T_2^* from 70 ms to 50 ms, as well as an intensity-drop of the vascular signal (Fig. 2d). Crushing has a similar effect in velocity selective ASL with crushed and non-crushed ASL signal becoming equal at a delay of approx. 1800 ms. Furthermore, the T_2^* of the label in VS-ASL is lower for the crushed data than for the non-crushed data Fig. 2c, but this difference is smaller than for PCASL. Finally, the T_2^* of the vascular signal is shorter in VS-ASL than in PCASL for short delay times. All these findings can be explained by labelling of venous blood that has a lower T_2^* than arterial blood and tissue. These results show, in agreement with earlier work of Wong et al, that vascular crushing for VS-ASL is not only important for arterial crushing, but also for elimination of venous signal [3]. Spin compartments were previously studied by multiple scans with each a different delay and different T_2-weighting by a non-selective T_2 preparation, whereas this study adopted the much faster option of multi echo, multi-delay time ASL in a single sequence. Although spin-echo imaging enables a direct link with literature values of e.g. arterial blood, we show in this work that also gradient echo imaging can be employed to observe the transition from the arterial towards the tissue compartment.

1) Wang, Uh, and Lu, ISMRM 2010; 2) Petersen et al, Magn. Reson.Med. 2006:p219-32;3) Wong et al, Magn. Reson.Med. 2006:p1334-1341

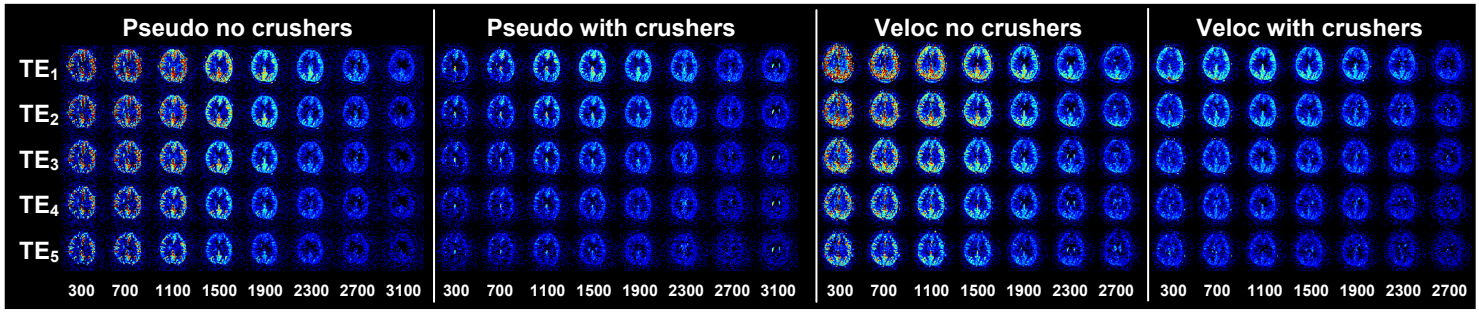

Figure 1: Example of multi-echo, multi readout-delay ASL maps in a single volunteer. Only half of the readout delays are shown. PCASL labeling (1650 ms labeling duration) on the left, velocity selective labeling (v_c = 1.5 cm/s) on the right. Both techniques are shown with and without vascular crushers (v_{enc} = 5 cm/s).

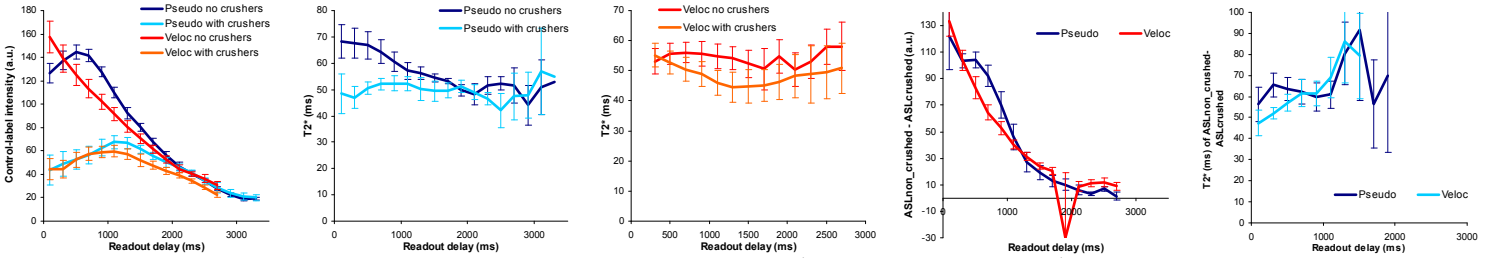

Figure 2a-e: From left to right (mean ± SEM): ASL-signal as a function of readout delay; T_2^* of ASL-signal for PCASL; T_2^* of ASL-signal for velocity selective-ASL; vascular signal (as calculated from $ASL_{non\text{-}curshed} - ASL_{crushed}$) as a function of readout delay; T_2^* of vascular signal (for longer readout delays the T_2^*-fit failed due to low signal).