Acceleration Selective Arterial Spin Labeling

Sophie Schmid[1], Eidrees Ghariq[1], Wouter M. Teeuwisse[1], Andrew Webb[1], and Matthias J.P. van Osch[1,2]
[1]*C.J. Gorter Center for High Field MRI, Dept. of Radiology, Leiden University Medical Center, Leiden, Netherlands,* [2]*Leiden Institute of Brain and Cognition, Leiden, Netherlands*

Introduction Velocity-selective arterial spin labeling (VS-ASL) tags spins on the basis of flow velocity instead of spatial localization, as is used in conventional ASL sequences. Therefore, VS-ASL can provide semi-quantitative measures of cerebral blood flow (CBF) even under slow and collateral flow conditions, since it has the capability to generate a label close to the capillaries within the imaging slice and does not suffer from errors due to long transit delay times[1]. A drawback of VS-ASL is the inability to discriminate between arterial and venous components. The use of a second velocity selective module in the sequence can exclude the venous components, as only the decelerated spins will be selected, but this also increases the diffusion-weighting. Recently it has been shown in magnetic resonance angiography that acceleration selective imaging can image the arteries exclusively [2]. This study investigates the use of an acceleration-dependent preparation module for ASL. This method, called Acceleration-selective ASL (AccASL), is demonstrated in healthy volunteers and compared with VS-ASL (with a single and double VS-module) and pseudo-continuous ASL (pCASL).

Materials and Methods To dephase the flowing spins' magnetization, motion-sensitizing gradients are used in both the velocity- and acceleration-selective labeling module, with the only difference being the sign of the second and fourth gradient, see fig. 1. The first gradient moment $m_1 = G\delta\Delta$ of the velocity- selective module has a v_{enc} of $\pi/(\gamma m_1)$ giving a π phase change. The first gradient moment of the acceleration selective module is zero, giving no velocity selectivity. However, the second gradient moment $m_2 = 4G\delta\Delta\tau$ has an a_{enc} of $2\pi/(\gamma m_2)$ yielding a π phase change. The labeling module parameters, which determine the velocity-sensitivity, were δ=0.7ms, Δ=26ms, G=22mT/m for VS-ASL, corresponding to a v_{enc} of 2 cm/s and δ=1ms, Δ=26ms, G=30mT/m, τ=14ms for AccASL. Control images of both VS-ASL and AccASL were acquired without motion sensitizing gradients to calculate the subtracted ASL images. VS-ASL was performed both with a single as well as a double VS-module (labeling delay of 1600 and a TR of 4272ms). The pCASL scan consisted of a labeling module of 16 50ms with 1525ms delay before multi-slice acquisition and a TR of 3863ms. Background suppression was applied using two inversion pulses at 1680 and 2760ms for pCASL and at 50 and 1150ms for the other scans.

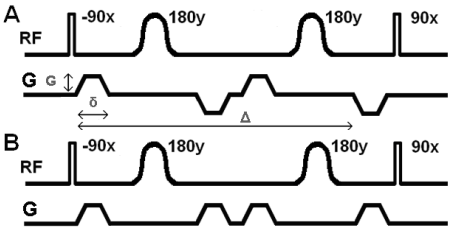

Figure 1: Velocity (A) and acceleration (B) selective module.

The 4 different labeling methods were applied in 8 healthy volunteers using 17 slices of 7mm thickness on a 3T Philips Achieva MRI scanner using a 32 channel head-coil. An average CBF-weighted scan was generated after co-registrating the images to a standard brain with SPM8 and was thresholded to obtain a grey matter (GM) mask. The different sequences were compared with a 2-way ANOVA statistical test using Matlab.

Results Volunteer data are shown in fig. 2. The SNR and mean signal intensity of the difference images of the GM and ASL signal from the GM, CSF and sagittal sinus are depicted in fig. 3. The ASL signal and SNR from GM using AccASL was significantly higher than single and dual VS-ASL: the signals from dual VS-ASL were lower than the other techniques. The ASL signal in the CSF and sagittal sinus using AccASL was lower than single VS-ASL and similar to the other methods.

Discussion and Conclusions The use of AccASL significantly improves the ASL signal from GM compared to both the single and dual VS-ASL, with SNR comparable to pCASL. Moreover, AccASL efficiently eliminates the vascular signal, especially venous, which is visible with the single VS-module, while almost completely absent with the other techniques. Since it does not have a second labeling module, such as in dual VS-ASL, AccASL does not suffer from lower SNR in GM due to T2 relaxation and differences in labeling efficiency during systole and diastole, since it is not triggered. Similar signal intensity is obtained for the single VS-ASL scans with the AccASL gradient strength and duration (data not shown), although it should be mentioned that the v_{enc} was decreased to 1 cm/s. A critical parameter in the design of the AccASL pulse sequence is the choice of the cutoff acceleration a_{enc}. An estimate of the flow acceleration in areas of interest may be an important part of the optimization of the AccASL technique: nevertheless quantification remains difficult. The proposed AccASL is a promising method to enable measurement of the perfusion with the advantages of dual VS-ASL to label spatially and non-selectively and to eliminate venous label, and of pCASL to provide a high signal in GM.

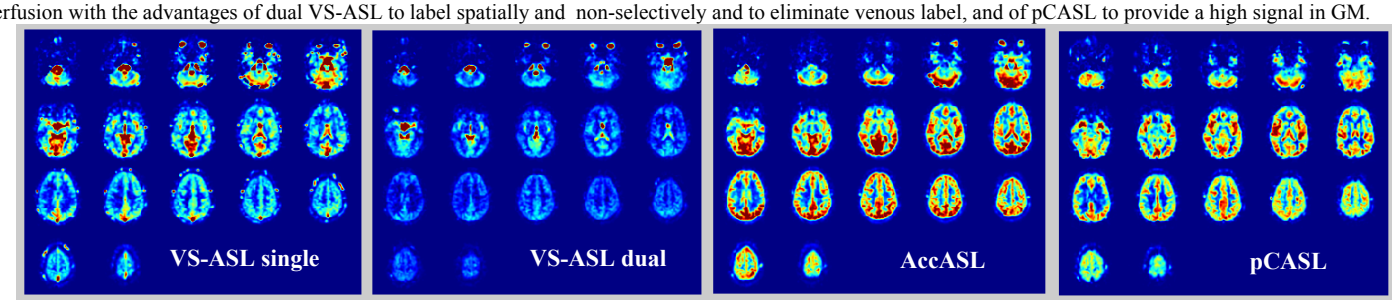

Figure 2: Example of the ASL maps in a single volunteer. From left to right: VS-ASL single, VS-ASL dual, AccASL and pCASL

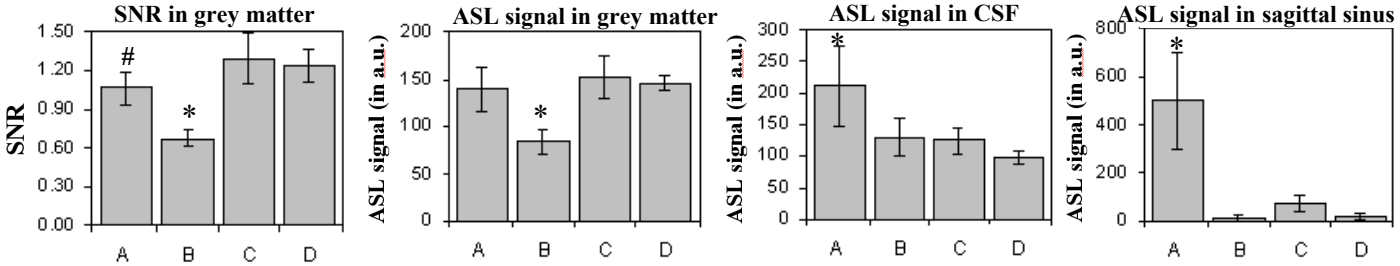

Figure 3: Mean SNR in GM and mean ASL signal in GM, CSF and sagittal sinus for single VS-ASL (A), dual VS-ASL (B), AccASL (C) and pCASL (D), * $p<0.05$ between group difference, 2-way ANOVA, #$p<0.05$ between single VS-ASL and AccASL difference, 2-way ANOVA

References [1] Wong et al. MRM 2006;55:1334–1341 [2] Priest et al. proc ISMRM 2011;19:90

Acknowledgement This research is supported by the Dutch Technology Foundation STW, applied science division of NWO and the Technology Program of the Ministry of Economic Affairs.