Insight into the labeling mechanism of Acceleration selective arterial spin labeling

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Purpose: Velocity selective ASL (VS-ASL)[1] and Acceleration-selective ASL (AccASL)[2] are spatially non-selective ASL methods, which tags spins based on their flow velocity or acceleration, respectively, rather than spatial localization as is the case in conventional ASL sequences. In this way they have the capability to generate label closer to the capillaries and within the imaging region, making them more robust with respect to transit time effects. For VS-ASL the location in the vasculature where label is created can be related to the cutoff velocity (V_{enc})[3], although the velocities in the vascular tree can vary from person to person depending on for example age and/or vessel stiffness. However, for AccASL it is unknown where in the vasculature label is created. It has been suggested that the label could originate from cardiac cycle fluctuations, general flow acceleration/deceleration in the vasculature and the tortuosity of the vessels, both at macro- and micro-vascular level. The aim of this study was to obtain more insight into the origin of the labeling mechanism in AccASL by combining this method with a VS module.

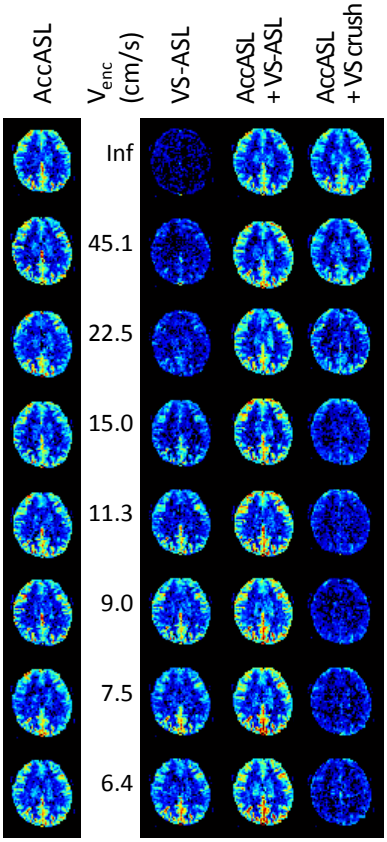

Figure 1: Example from a single subject for the different V_{enc} of "AccASL", "VS-ASL", "AccASL and VS-ASL", and "AccASL with crushing due to VS-ASL" normalised to the AccASL signal.

Materials and Methods: The sequence used in this study consisted of an Acc-labeling module with fixed gradient settings (δ=1ms, Δ=26ms, τ=14ms, G=30mT/m), immediately followed by a VS-labeling module (δ=1ms, Δ=26ms, G=[0:0.5:3.5] mT/m), corresponding to a V_{enc} of infinity, 46.7, 23.4, 15.6, 11.7, 9.4, 7.8 and 6.7cm/s, respectively. The AccASL and VS-ASL combination was performed in 7 healthy volunteers (5m/2f, age 19-55yrs) on a 3T Philips Achieva system using a 32-channel receive head-coil. 17 slices were acquired with a voxel size of 3x3x7mm and TR/TE=4108/15ms with two inversion pulses at 50 and 1150ms for background suppression, applied during the post labeling delay of 1600ms. The sequence cycled through four different labeling combinations: a control and/or label condition for the Acc and/or VS labeling module (A_CV_C, A_LV_L, A_CV_L and A_LV_C), each averaged 96 times in a total scan duration of 26 min: 12 averages were acquired for each V_{enc}. The difference between A_CV_C and A_LV_C will result in signal similar to that obtained by a normal single Acc labeling module, A_CV_C minus A_CV_L gives the signal only originating from the VS module, A_CV_C minus A_LV_L results in the signal created by joint, sequential application of the VS and Acc module, and the subtraction of A_LV_L from A_CV_L will provide the signal from the Acc module followed immediately by crushing from the VS module. All scans were motion corrected in FSL and, after subtraction, thresholded to obtain a grey matter (GM) mask in Matlab. The different labeling combinations were normalised to the AccASL signal by dividing by the average AccASL signal intensity in the GM and were compared with each other using a paired t-test.

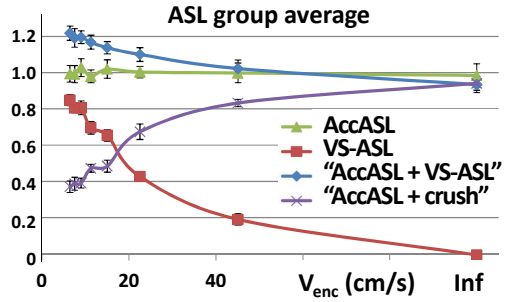

Figure 2: Group averages of "AccASL"(A_CV_C-A_LV_C, green) "VS-ASL"(A_CV_C-A_CV_L,red), "AccASL and VS-ASL"(A_CV_C-A_LV_L,blue), and "AccASL with crushing due to VS-ASL"(A_CV_L-A_LV_L,purple) normalised to AccASL GM signal.

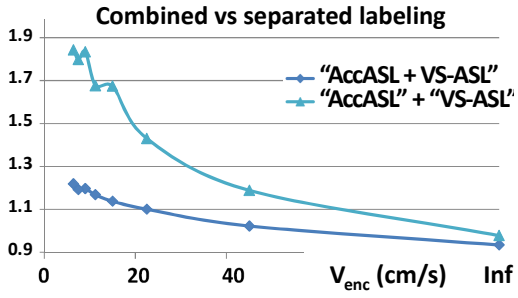

Figure 3: The differences in signal intensity of group averages between AccASL and VS-ASL acquired immediately after each other (A_CV_C-A_LV_L) and acquired separately (A_CV_C-A_LV_C) + (A_CV_C-A_CV_L).

Results: For VS-ASL (A_CV_C-A_CV_L) at the highest V_{enc} no significant label is created and the more V_{enc} decreases, the more signal is created, up to 85% of the AccASL signal strength in GM for a V_{enc} of 6.7 cm/s, as shown in figure 2. For the 3 smallest values of V_{enc} an almost constant signal intensity was found for both VS-ASL (0.82) and AccASL with crushing (A_CV_L-A_LV_L , 0.38). After crushing with a V_{enc}=6.7cm/s 38% of the AccASL signal remained, which indicates that it originated from a region with a flow velocity smaller than 6.7cm/s. To test whether AccASL labels other spins than VS-ASL at a certain V_{enc}, the combined sequential labeling with the Acc and VS module (A_CV_C-A_LV_L) was compared with the sum of the signal of both labeling modules acquired separately (A_CV_C-A_LV_C) + (A_CV_C-A_CV_L), see figure 3.

Discussion and Conclusion: Summing the signal of AccASL and VS-ASL scans acquired separately results in a higher signal intensity compared with AccASL and VS-ASL acquired immediately after each other (up to 62% for the lowest V_{enc}). This indicates that AccASL shares in part the same label origin as VS-ASL for a V_{enc} smaller than 25cm/s. This is confirmed by a slight, but significantly higher signal (up to 22% for the lowest V_{enc}) when performing VS-ASL immediately after AccASL compared with only AccASL , shown by the blue and green lines in figure 2. The slightly higher signal points to the fraction of the spins that is only labeled by VS-ASL and not by AccASL. Furthermore, it can be concluded that approximately 40% of the AccASL signal originates from spins which are only labeled by AccASL and not by VS-ASL with a flow velocity smaller than 6.7cm/s. From these results it can be concluded that AccASL is able to label spins in both the macro- as well as micro-vascular region. Therefore a part of the AccASL label must be created in slower flow velocity regions, i.e. closer to the capillaries.

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. **References:** [1] Wong et al., MRM 55: 1334–1341, 2006, [2] Schmid et al., MRM epub, 2013, [3] Piechnik et al., NeuroImage 39:107-118, 2008