Comparison of velocity and acceleration selective arterial spin labeling with ^{15}O H_2O positron emission tomography.

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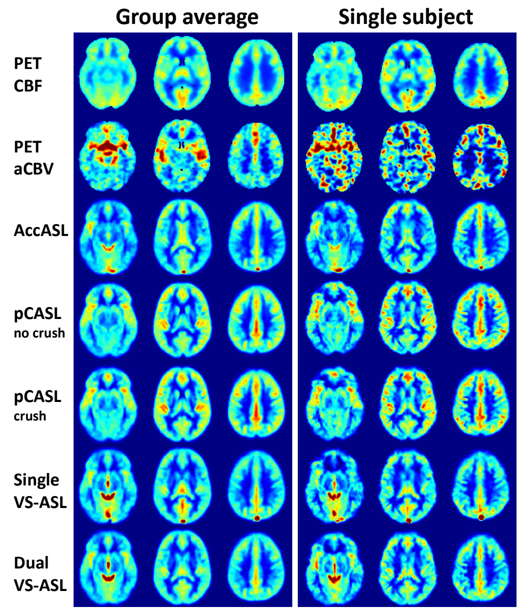
Purpose: Pseudo-continuous arterial spin labeling (pCASL) is nowadays regarded as the most reliable and robust ASL technique[1], although quantification is sensitive to increases in arterial transit time. Velocity-selective ASL (VS-ASL)[2,3] and acceleration-selective ASL (AccASL)[4] are spatially non-selective ASL methods that tag spins based on their flow velocity or acceleration, respectively, instead of spatial localization. These non-spatial ASL methods label, therefore, spins within the imaging plane, making them more robust against transit time effects. The aim of this study was to compare AccASL and VS-ASL with ^{15}O H_2O PET.



Materials and Methods: VS-ASL (both with single and dual velocity encoding modules, v_{enc}=2cm/s, delay=1600ms) and AccASL (δ=1ms, Δ=26ms, G=30mT/m, τ=14ms, delay=1600 ms) were performed in 12 healthy volunteers (6m/6f, age 20-24 yrs.) on a 3T Philips Intera system using an 8-channel receive head-coil. pCASL-scans (1650ms labeling and 1525ms delay, acquired with and without flow crushing gradients) were acquired to serve as references. PET scans were performed on a Philips Gemini TF-64 PET/CT system (800 MBq bolus; 25 frames with progressively increasing duration; total duration 10min; processing provided both cerebral blood flow (CBF) and arterial cerebral blood volume (aCBV) maps; aCBV maps can be affected by delay and dispersion effects, which was checked for by visual inspection leading to the exclusion of 3 subjects). Images were motion corrected and registered into MNI-space using FSL. The average of all scans was thresholded to obtain a grey matter (GM) mask. The scans were compared to PET by calculating voxel-wise correlations (R^2) between individual ASL and PET scans. A Bland-Altman analysis was performed to compare dual VS-ASL (the only *quantitative* non-spatial ASL scan)[5] with PET CBF[6]. To study whether the ASL methods are (also) sensitive to aCBV, the group-averaged maps were correlated with a weighted sum of PET CBF and PET aCBV (performed only with the non-quantitative data, n=9) to compare the relative distribution of the signal in the maps. The aCBV-fraction at maximum R^2 was interpreted as the aCBV contribution of the ASL scan.

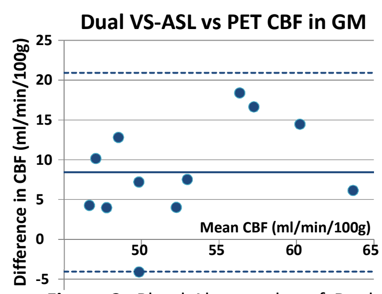


Figure 2: Bland-Altman plot of Dual VS-ASL versus PET CBF.

Table 1: Whole brain correlation coefficient, R^2, (mean ± SD) of ASL versus PET CBF evaluated at subject level (n=12).

	AccASL	$pCASL_{nocrush}$	$pCASL_{crush}$	Single VS-ASL	Dual VS-ASL
Correlation with PET CBF	0.88 ± 0.04	0.92 ± 0.02	0.93 ± 0.02	0.85 ± 0.05	0.92 ± 0.02

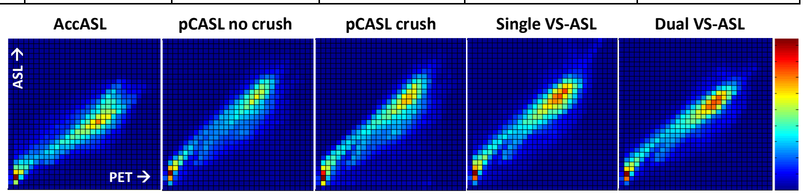


Figure 3: Voxelwise correlation density of ASL versus PET CBF of whole brain intensity normalised group averaged maps (see colorbar).

Results: The group average and a single subject example are shown in Figure 1 and the Bland-Altman plot of dual VS-ASL and PET-CBF (mean GM CBF of 56.9±7.4 and 48.5±5.2ml/100ml/min, respectively) in Figure 2. Table 1 shows comparable R^2 for dual VS-ASL as for pCASL; AccASL and single VS-ASL show lower R^2, evaluated voxelwise at the single subject level. Maximizing R^2, with respect to a weighted sum of PET CBF and aCBV, showed only minor aCBV information from AccASL (see Table 2, evaluated on the group averaged maps). In Figure 3 the whole brain intensity normalised group average of the ASL signal is plotted versus PET-CBF voxelwise.

Discussion and Conclusion: Quantitative VS-ASL (i.e. two VS modules separated by 1.6s) overestimated GM CBF by 17% compared to PET. With only a single VS module the mean correlation with PET CBF was lower and comparable with AccASL. It has been postulated that both single VS-ASL and AccASL would be more CBV- than CBF-weighted, since they label all blood in the imaging plane within a certain velocity/acceleration range. The lower R^2 with PET-CBF seem to support this hypothesis. However, by maximizing the R^2 as a function of a weighted sum of PET CBF and aCBV maps using group-averaged maps, a relative lower contribution was found than for pCASL. This could be explained by more weighting towards total CBV than aCBV for single VS-ASL and AccASL. Finally, it should be noted that the change in R^2 by including a fraction of aCBV was minor for all scans.

Table 2: Whole brain correlation coefficient of ASL with weighted sum of group averaged PET CBF and aCBV maps (n=9).

	AccASL	$pCASL_{nocrush}$	$pCASL_{crush}$	Single VS-ASL	Dual VS-ASL
Max correlation	0.87	0.87	0.87	0.79	0.84
% contribution of PET-aCBV	13	35	37	24	38

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References: [1] ASL white paper, MRM, 2013, [2] Wong et al., ISMRM, Abstracts p.621, 2002, [3] Wong et al., MRM 55: 1334–1341, 2006, [4] Schmid et al., MRM epub, 2013, [5] Wu et al., NeuroImage *32*(1): 122–128, 2006, [6] Boellaard et al., Mol Im Biol 7: 273-285, 2005