Comparison of Non-Selective and Vessel-Encoded Pseudocontinuous Arterial Spin Labeling for Cerebral Blood Flow Quantification

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Introduction: Absolute cerebral blood flow (CBF) quantification allows the objective assessment of brain tissue perfusion, aiding diagnosis, prognosis and therapeutic decision making in patients with cerebrovascular diseases and stroke. Arterial spin labeling (ASL) allows such measurements to be made non-invasively. To reduce the impact of potential confounds, such as blood transit time, it is advantageous to fit a kinetic model [1] to ASL data at a range of inflow times (TIs). However, in patients with significant collateral flow and in certain normal variants of the vascular architecture, some brain regions are fed by multiple arteries, each with a different transit delay. In these situations fitting a single kinetic curve will likely not result in an accurate assessment of CBF. We propose using vessel-encoded pseudocontinuous ASL (VEPCASL) [2] that allows spatial encoding of arteries within the labeling plane and hence artery-specific perfusion maps. A kinetic curve can then be fitted to each arterial component independently, which we hypothesize will improve the accuracy of CBF quantification. For favorable vascular geometries the signal-to-noise ratio (SNR) is theoretically [2] comparable to non-selective (NS) pseudocontinuous ASL (PCASL) [3]. Here, we assess the potential benefits of using VEPCASL for CBF quantification by comparing SNR and CBF estimates against standard PCASL in healthy volunteers.

Methods: Six healthy volunteers (1 female, mean age 29.5) were recruited and scanned on a Siemens 3T TIM Verio system with a 32 channel head coil under a technical development protocol agreed with local ethics and institutional committees. A 3D multi-slab time-of-flight acquisition was used for labeling plane selection and vessel localization. Both PCASL and VEPCASL acquisitions shared a common labeling plane positioned where the four main brain-feeding arteries form an approximately rectangular arrangement. Vessel-encoding of the right and left internal carotid arteries (RICA and LICA) and right and left vertebral arteries (RVA and LVA) was performed with eight paired encoding cycles: non-selective tag and control, two left-right encodings, two anterior-posterior encodings and two diagonal encodings. All parameters were kept constant between the two scans: single-shot echo planar imaging (EPI) readout, voxel size 3.4 x 3.4 x 5 mm, 24 slices, TE 14 ms, 6/8ths partial Fourier, TR 4.05 s, tag duration 1.4 s, post-labeling delays 0.25, 0.5, 0.75, 1.0, 1.25 and 1.5 s, 96 volumes, acquisition time 6.5 mins. Background suppression was provided by pre-saturation of the imaging region and two global hyperbolic secant inversion pulses following the VEPCASL pulse train, similar to [4]. Additional calibration scans (TR = 6s) were performed with both head and body coils for signal reception to allow correction for coil sensitivity variation over space and calibration of CBF in absolute units. Separation of vascular components in the VEPCASL data was performed using a maximum *a posteriori* solution [5] to the Bayesian framework of [6] with two vessels per class, which can account for rigid subject motion between scans. Signal calibration was performed using cerebrospinal fluid as a reference (as per [7]) before fitting the general ASL kinetic model within a brain mask using a Bayesian framework and allowing for a macrovascular component [8]. Fitting to the VEPCASL data was performed for each vascular component separately.

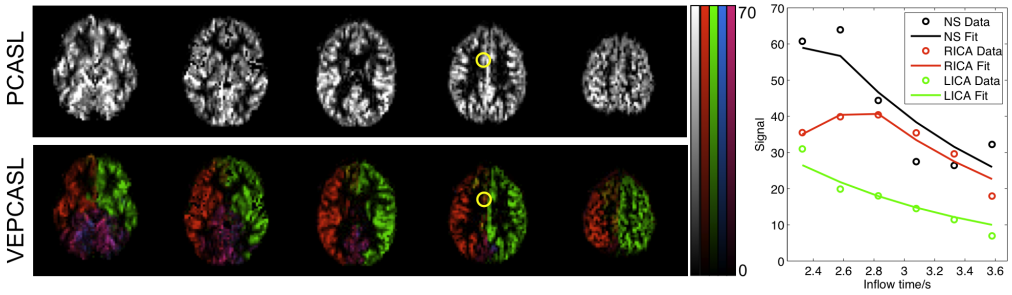

Figure 1: Quantitative CBF maps (left) using standard PCASL (top) and VEPCASL (bottom) in units of ml/100ml/min. Color represents the origin of the blood signal (red = RICA, green = LICA, blue = RVA, magenta = LVA). Example data and fits within the circled voxel are shown (right) for non-selective (NS) PCASL and the two ICAs from VEPCASL.

Results: Example CBF maps produced by the fitting procedure for both PCASL and VEPCASL are shown in Fig. 1. Qualitatively these show similar information, with VEPCASL providing additional information about the arterial source of the blood signal. In this subject the right anterior cerebral artery territory is supplied by both ICAs. The example voxel shown demonstrates that fitting to the vascular components separately allows arrival time differences between multiple feeding arteries to be properly accounted for. In this case this leads to a difference in the estimated CBF of 19%. However, in these healthy volunteers few voxels are fed by multiple arteries with different arrival times, so on average the CBF calculated with both methods is very similar. Fig. 2 shows the mean of the ratio of VEPCASL (summed over vascular components) to PCASL CBF estimates in voxels where the PCASL CBF is greater than 5 ml/100ml/min across subjects. The ratio values are close to one, indicating that VEPCASL provides comparable CBF quantification to PCASL. A two-tailed paired Student's t-test of the mean grey matter CBF across subjects confirms there is no significant difference between the two methods ($p = 0.14$). SNR was calculated using the mean perfusion signal within the grey matter mask and the noise standard deviation in a background region. These indicate that standard PCASL yields 77 ± 34 % higher SNR than VEPCASL, which can be attributed to non-ideal vascular geometry and/or subject motion between the TOF and VEPCASL scans, both of which reduce the VEPCASL encoding efficiency.

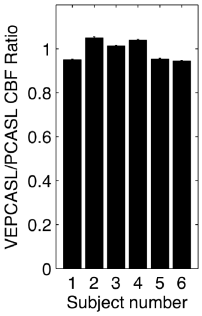

Figure 2: Mean ratio of CBF calculated using VEPCASL (summed over all vascular components) to that calculated using standard PCASL across subjects.

Discussion: A multiple TI VEPCASL acquisition yields quantitative CBF measurements comparable to standard PCASL in the same scan time. The ability to separately fit the labeled bolus from each feeding artery is likely to be advantageous in patient groups where significant collateral flow and delayed transit through diseased vessels can occur. However, for collateral flow originating above the circle of Willis, labeling smaller arterial branches may be necessary. The reduced relative SNR of the VEPCASL acquisition is likely to be improved by using a unipolar VEPCASL preparation [9] which has wider tag and control regions, making it less sensitive to imperfect vascular geometry and subject movement.

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References:

[1] Buxton, MRM 40:383-96 (1998)
[2] Wong, MRM 58: 1086-1091 (2007)
[3] Dai, MRM 60:1488-97 (2008)
[4] Günther, MRM 54:491-498 (2005)
[5] Chappell, ISMRM (2011): #366
[6] Chappell, MRM 64:1529-39 (2010)
[7] MacIntosh, JCBFM 28:1514-1522 (2008)
[8] Chappell, MRM 63:1357-65 (2010)
[9] Wong, ISMRM (2011): #294