Feasibility of velocity selective arterial spin labeling in functional MRI

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Introduction

In MR perfusion imaging, velocity selective arterial spin labeling (VS-ASL) tags arterial blood according to its flow velocity rather than spatial distribution as is commonly used in conventional ASL methods (1,2). One desirable characteristic of VS-ASL is its capability to tag blood close to the slice of interest with a transit delay (δt) of zero, which makes it a promising candidate in multi-slice or volume imaging without the complication of δt variation. The feasibility of VS-ASL has been demonstrated in baseline CBF measurement (2) but not in fMRI study yet. In this abstract, we show a comparison between VS and conventional ASL methods in fMRI experiments.

Materials and Methods

Visual stimulation was performed using a black-white radial flashing checkerboard with a paradigm of a preceding 30s OFF-period followed by 4 cycles of 24s ON-period and 36s OFF-period. VS pulse train comprised non-selective 90^0-180^0-90^0 RF pulses in combination with a pair of flow sensitive gradients. Background suppression was incorporated to increase the contrast to noise ratio with two inversion pulses 1550ms and 450ms prior to imaging acquisition (3). TR/TE/TI = 3000/14/1600 ms. FOV = 22cm, matrix size = 64x64, cutoff velocity = 2cm/s, single 7mm slice parallel to the calcarine sulcus. Flow encoding was separately applied along three orthogonal directions (anterior-posterior, left-right and superior-inferior) in three scans. For comparison, conventional ASL data was acquired using PICORE (4) QUIPSS II (5). TR/TE/TI1/TI2 = 3000/2.9/700/1400 ms. Data were collected by a single shot spiral spin echo sequence for VS-ASL and gradient echo for PICORE ASL. To quantify flow, a reference image and a high-resolution proton-density-weighted image were acquired (4). CSF was used as the reference tissue. Baseline drift was corrected by fitting signal-time curves to a non-linear function prior to correlation coefficient analysis. Activated pixels were detected by following criteria: c.c. = 0.35, p <= 0.05, cluster size = 3. Three healthy volunteers (1 female, 2 males, 29-37 years) were included in this study and all gave written consent before participating. All imaging was performed on a 3T EXCITE GE scanner.

Results and Discussion

Compatible activated region is found using VS and PIOCRE ASL (Fig 1). Signal-time curves are extracted by averaging over the pixels detected by both methods (Fig 2). While no significant difference exists in rising time and post-activation response, ASL signal change ($\Delta ASL = ASL_{on}/ASL_{off} - 1$) is consistently higher in VS. ASL signal is converted to flow (ml/100ml/min) and the quantitative value is marked for baseline and peak (Fig 2). Flow is substantially underestimated when VS encoding is applied along superior-inferior direction that mostly deviates from the direction of arteriolar flow in visual cortex. The mismatch between flow and VS encoding directions leads to tagging failure. To be tagged by VS-ASL, spins need to flow at a velocity higher than the cutoff velocity along the direction of flow-sensitive gradients. In other words, a vessel perpendicular to the VS encoding is never tagged, regardless of flow velocity. The angle between flow and VS encoding shifts tags toward upstream. Beyond a degree, tags fall outside the target plane and δt is no longer zero, which results in flow underestimation (especially in OFF-period as flow is slower) and hence erroneous larger ΔASL. A related issue originates from the faster flow when neuronal activity increases. Velocity variation could change tagging region and complicate the localization in activation pixels. We investigate this effect by subtracting the perfusion maps at ON and OFF periods. No residual displacement is found with the used voxel size (3.4x3.4x7 mm^3). Besides activation mapping, VS-ASL further provides information of vasculature that contributes to neuronal activity from different flow direction. In visual cortex, flow is mostly along anterior-posterior and left-right directions, whereas the medial region is simultaneously contributed by orthogonal flows. Meanwhile, caution has to be taken when averaging ΔASL over multiple directions of VS encoding.

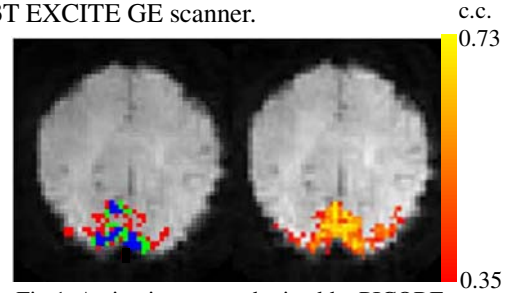

Fig 1. Activation maps obtained by PICORE (right) and VS ASL (left; red, green and blue indicate voxels detected by 1, 2 and 3 directions of VS encoding, respectively).

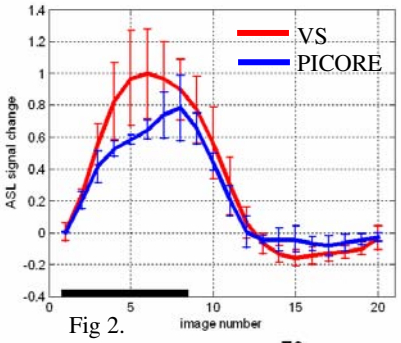

Fig 2.

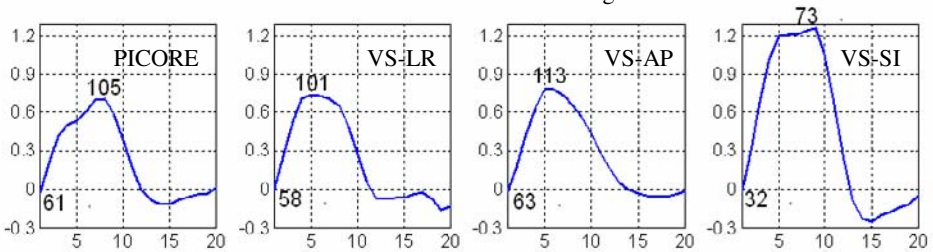

Fig 3. Signal time curves (x-axis: image number, TR = 3000ms; y-axis: ASL signal change). Quantitative perfusion is marked for baselines and peaks, in ml/100ml/min.

References

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