Intravascular effects in velocity-selective arterial spin labeling: the choice of transit delay and cutoff velocity

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Introduction

Velocity selective arterial spin labeling (VS-ASL) creates a modulation of longitudinal magnetization of blood on a basis of flow velocity (1,2) rather than spatial distribution as has been commonly used in conventional ASL methods. By incorporating a VS pulse train, only blood flowing above a cutoff velocity (V_c) is tagged. Theoretically, VS-ASL is capable of generating tags very close to the region of interest and thereby avoids the confounding error coming from transit delay (T_v). In practice, however, T_v of VS-ASL should still be chosen with caution in consideration of intravascular signal and V_c. This study tries to investigate the influence of large vessels and evaluate the optimal T_v for different V_c at motor cortex.

Materials and Methods

In the presence of laminar flow, a 90^0-gradient-180^0-gradient-90^0 pulse train can be used to tag spins by generating a sinc-shaped profile of longitudinal magnetization vs. flow velocity (1-3). In this study, the 180^0 pulse was replaced by a pair of identical adiabatic 180^0 pulses for the purpose of reducing the effect of RF inhomogeneity (4). After a delay T_v allowing for the delivery of tags, single shot spin echo spiral images were acquired with flow weighting gradients that were adjusted to the same V_c as the tag pulse. In other words, the ASL signal only included blood that was tagged at velocities above V_c, and then decelerated to a velocity below V_c prior to imaging. The ASL signal was therefore in principle proportional to CBF$\cdot T_v \cdot \exp(-T_v/T_{1b})$, where T_{1b} was the longitudinal relaxation time of blood. The flow-sensitive gradients were applied along three orthogonal directions. Relevant imaging parameters included: FOV=24cm x 7mm, T_v={300, 500, 700, 900, 1100, 1300, 1500}ms, V_c ={1, 2, 8}cm/s, TR=2500ms. Imaging was performed on a 3T GE EXCITE system on healthy volunteers. Image masks were created by thresholding the ASL images obtained by T_v=300ms and 1500ms with different V_c. We assumed that 1500ms delay was enough for tags to reach capillary beds whereas most of the tag remained in arterioles or arteries at 300ms.

Results

Figure 1 shows the difference between VS-ASL images acquired with V_c=2cm/s and 8cm/s. Subtracting high V_c from low V_c and the reverse indicate the mismatch at small (upper row) and large vessels (lower row), respectively. When T_v increases, allowing high-speed tags to decelerate into capillaries, the mismatch decreases in the scope of small vessels. On the other hand, noticeable mismatch in large vessels is found through different T_v. The influence of large vessels under high V_c can be further demonstrated by figure 2. The ASL signal extracted by a mask of large arteries shows an early peak in contrast to the signal at tissue and capillary bed. The discrepancy on the other hand is not found when V_c is below 2cm/s. Table 1 shows the calculated diffusion-related attenuation in CSF and brain tissue caused by the tag pulse train. CSF artifact for V_c > 1cm/s is negligible.

Discussions and conclusions

Significant signal from large vessels are present in VS-ASL images for V_c of 8 cm/s. Lower V_c is recommended for quantitative measurement of tissue perfusion and the optimal T_v for V_c=1-2 cm/s at motor cortex is ~900ms. In this study, the lower amplitude and longer separation of diffusion gradients in the VS pulse train reduces b value and thereby obviates the necessity of CSF suppression for V_c down to 1cm/s, making VS-ASL more time efficient (2,5).

References

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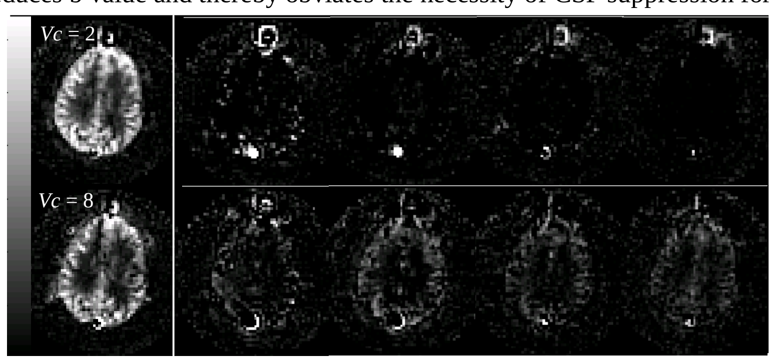

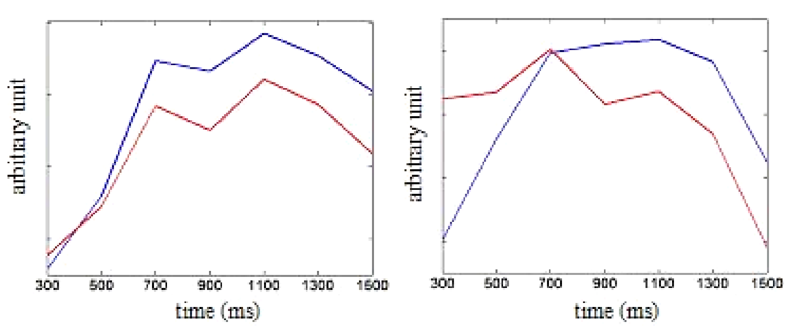

Fig 1. Subtraction between ASL signals obtained with two different V_c. V_c=2 minus V_c=8 (upper row); V_c=8 minus V_c=2 (lower row). From left to right, T_v ={300, 700, 1100, 1500}ms.
Fig 2. ASL signal vs. transit delay (left V_c=2, right V_c=8). Two masks were used by thresholding ASL images that were acquired with V_c=2cm/s, T_v=1500ms (blue) and V_c=8cm/s, T_v=300ms (red). Two ASL images were shown at the most left column in the same scale.

Table 1. Diffusion-related attenuation caused by the tag pulse train

Vc (cm/s)	1	2	8
$1-e^{bD}$ (CSF)	0.227%	0.057%	0.004%
$1-e^{bD}$ (brain)	0.091%	0.023%	0.001%