Velocity Selective Arterial Spin Labeling in Rat Brain

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INTRODUCTION: Velocity Selective Arterial Spin Labeling (VSASL) is an ASL-based perfusion MRI technique [1,2,3] that magnetically labels blood spins based on their velocity instead of their spatial position. With VSASL all spins above a specified cut-off velocity are labeled (velocity selective labeling, VSL), and after a certain inflow time (TI), imaging is performed of the region of interest. Immediately before imaging all spins with a velocity above the cut-off velocity are dephased with a vascular crusher (VC) gradient. Labeled arterial spins will have decelerated, and thus will be detectable in the image, while labeled venous spins have accelerated and due to the crushing will not be detectable.
VSASL can label blood very close to the capillary bed. This allows a more reliable perfusion quantification under conditions of collateral, delayed or slow flow, since the transit time from labeling position to imaging slab is reduced. This characteristic makes VSASL a very suitable technique to assess perfusion in cerebrovascular disorders, e.g. stroke, both in patients and animal models. However, thus far VSASL perfusion imaging has not yet been assessed for application in an animal model.

MATERIALS AND METHODS: The VSASL sequence was implemented on a 9.4T Varian MR-scanner with a 72 mm quadrature volume coil (Rapid Biomedical). The sequence consisted of a velocity selection part followed by FLASH acquisition (TR/TE=30/3 ms, FA=20°, matrix=32x32, FOV=32 mm, 2-mm slice thickness, acquisition time 5 s). For the preparation part hard pulses were combined with two positive gradients. The sequence was tested in two adult Wistar rats. One rat was sacrificed while continuously performing VSASL measurements to examine the effectiveness of subtraction of the label and control images. Images were processed with Matlab.

RESULTS: For one rat the gradient amplitude was varied to find an optimal cut-off velocity (shown in figure 1). The perfusion-weighted signal increased with decreasing cut-off velocity. Based on similar experiments in humans [2], a cut-off velocity of 2 cm/s was chosen for further experiments. With this cut-off velocity the inflow time was varied (depicted in figure 2). Comparable results were obtained in both rats. The optimal TI was determined to be around 1 s. In figure 3 a comparison is made between experiments carried out with and without VC at a short and optimal TI. It is clear that vascular crushing is mainly necessary to remove unwanted arterial and vascular signal. In figure 4a and 4b the results from the termination experiment are shown. 28 subtraction images of 64 averages with cut-off velocity =1.24 cm/s and VC of the same value were acquired. The first image depicts the normal state; during the acquisition of image 2 and 3 perfusion may have been elevated as the rat was asphyxiated. After the fourth acquisition the rat has died and the subtraction signal decreases to the noise level.

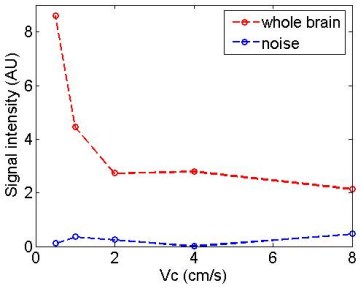

Figure 1: Subtraction signal as a function of cut-off velocity, in two ROIs. Images acquired with TI=1000 ms, nex=128 and VC=1 cm/s

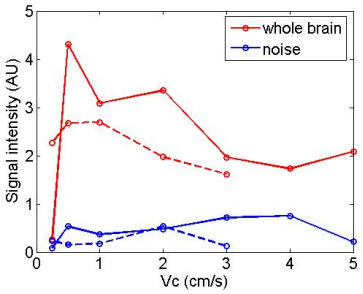

Figure 2: Subtraction signal as a function of inflow time. Rat 1 (solid): nex=64, cut-off velocity=1.24 cm/s, VC=1.24 cm/s. Rat 2 (dashed): nex=128, cut-off velocity=2 cm/s, VC=4.7 cm/s

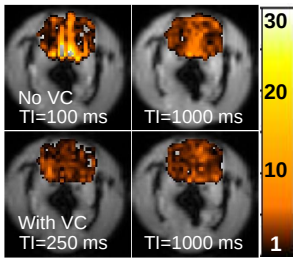

Figure 3: Control images with colored overlay of subtracted signal in brain. Comparison of short and long inflow time, with and without VC (cut-off velocity=2 cm/s, VC=4.7 cm/s)

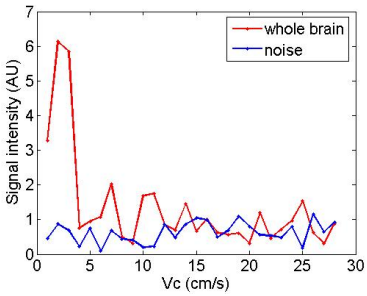

Figure 4a: Termination experiment: 28 images with nex=64, TI=1000 ms, cut-off velocity=1.24 cm/s, VC=1.24 cm/s

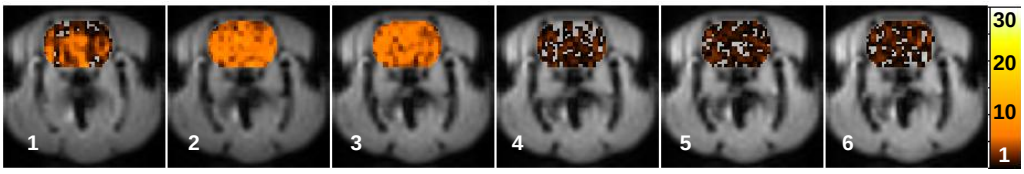

Figure 4b: Termination experiment rat1, first 6 images of 28 in figure 4a. (TI=1000 ms, cut-off velocity=1.24 cm/s, VC=1.24 cm/s)

DISCUSSION & CONCLUSION: In this study we have shown that VSASL can be used to measure perfusion in rat brain. The effectiveness of the measurement is demonstrated in the termination experiment, where the contrast in the subtraction image reaches the noise level when the rat dies. Furthermore, experiments with multiple inflow times indicate that the blood inflow signal remains in the same range for both rats; after quantification this will result in comparable perfusion values.
The choice of the optimal cut-off velocity is difficult in these experiments. The experiments did show an optimal cut-off velocity for the chosen inflow time. Decreasing the cut-off velocity will require an increasing gradient strength which causes increasing diffusion weighting. In these experiments the cut-off velocity was chosen to be between 1 and 2 cm/s, based on the findings in human studies [2]. The optimal inflow time corresponding to this cut-off velocity appears to be between 0.5 and 1 s.
Vascular crushing is necessary to remove the influence of large arteries and vascular blood from the subtraction images. Even though the experiments were performed at 9.4T, the contrast to noise severely limits the resolution and time-scale for the perfusion experiments. This may be improved by using EPI acquisitions and (multi-channel) surface coil arrays.

REFERENCES: [1] Duhamel, G et al., 2003, MRM 50:145-153, [2] Wong, EC et al., 2006, MRM 55:1334-1341, [3] Wu, WC et al., 2006, NeuroImage 32:122-128.