Using Magnetization Transfer (MT) to Enhance SNR and CNR for VASO MRI

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Introduction: Vascular-space-occupancy (VASO)-dependent MRI (1) produces micro-vascular cerebral blood volume (CBV)-weighted images by employing inversion recovery (IR) to null the blood signal. Depending on the TR used, the residual magnetization in gray matter (GM), however, is only about 10-20% of the equilibrium signal intensity at the time of inversion (TI), which yields a relatively low SNR. It is known and verified again in this study that blood has very little MT effect (2,3), especially when the irradiating frequency offset is far away from water (>40ppm). Therefore it should be possible to use MT to modulate the tissue signal with minimal effect on blood. We demonstrate that by applying an MT pulse before or after the VASO inversion pulse (Fig.1), we can prepare a smaller magnetization before inversion and accelerate the recovery process after inversion to obtain a higher GM signal and consequently boost the SNR and CNR of VASO at the same TI.

Materials & Methods: Visual stimulation with black/white flashing checkerboard (63s off/35s on; 4 repetitions) was performed (n=5). Three functional experiments were carried out for each subject: 1) VASO (TR/TE/FA/TI=7sec/4.9ms/90˚/1106ms); 2) An MT pulse (block shape, 500ms, 3μT, frequency offset -40ppm) was added immediately in front of the VASO inversion pulse (Fig.1. sequence I). 3) An MT pulse (block shape, 300ms, 3μT, frequency offset -40ppm) was added immediately after the VASO inversion pulse (Fig.1. sequence II). The same VASO sequence was used for all three experiments. Voxel volume = 2x2x5 mm^3, SENSE=2, single-shot TSE with a low-high profile order (lower frequency k-space line acquired first). The SAR shown on the scanner for 2) and 3) was 0.9W/kg and 0.8W/kg respectively. A SE image was acquired as the equilibrium signal intesity (TR/TE/FA =7sec/4.9ms/90˚, 2x2x5 mm^3, SENSE=2, multi-shot TSE, TSE factor=4). Requirements for voxel activation were z-score<-2.5, p-value<0.01, SNR>20, and cluster size ≥ 4.

Results & Discussion: First we verified the blood nulling point for each sequence in both bovine blood phantom and *in vivo* human brain (sagittal sinus). An image for each sequence was acquired at the VASO TI (1106ms) (4). The blood signals were all in noise range. Therefore the same TI was used for all three sequences. Figs. 2a-c show the representative activation maps of one subject. The location of the activated voxels is well reproduced in all maps while the activation areas in sequence I and II are larger than in VASO. This implies higher MR sensitivity of sequence I and II, which can also be judged by the number of activated voxels (P<0.01), averaged z-score (P<0.01) and CNR (P<0.01) shown in Table.1. The voxels that were activated in all three sequences were used for further evaluation. The averaged magnetizations at TI normalized by the equilibrium signal are shown in Table.1. Compared to VASO, sequence I and II have increased SNR by 50% and 40%, respectively. The hemodynamic responses averaged over all subjects (for each subject the four repetitions in one paradigm were averaged, 3 points in the beginning of 1st off and 6 points in the end of last off were dropped) and task periods are shown in Fig.2d. Both the time courses and amplitudes of relative signal changes between rest and activation match in all three sequences. Since SNR increases while relative signal changes are unchanged, the CNR was enhanced by around 45% and 35% for sequence I and II, respectively, compared to the original VASO sequence.

Conclusion: We improved the SNR and CNR for VASO MRI by adding an MT pulse into the VASO sequence.

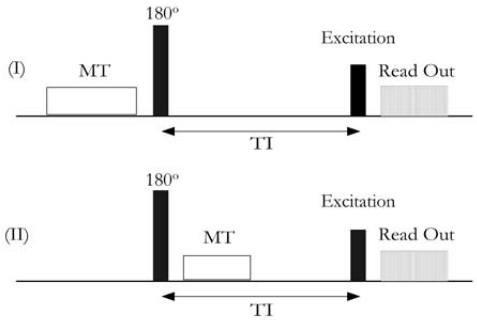

Fig.1. The pulse sequences with corresponding tissue recovery curves.

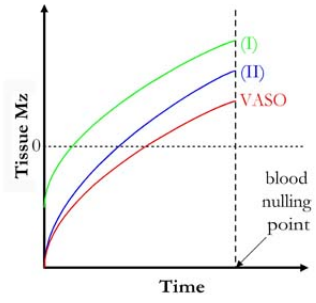

Table.1 (n=5)	Number of Activated Voxels	Normalized M_z @ TI (%)	Averaged Z-score	SNR	CNR
VASO	503±98	21.3±3.2	-4.40±0.25	485.3±59.4	9.8±1.2
Seq.I	931±56	37.8±5.6	-5.27±0.33	721.3±35.1	14.2±1.3
Seq.II	737±67	33.1±4.8	-4.91±0.09	670.1±17.4	13.3±1.1

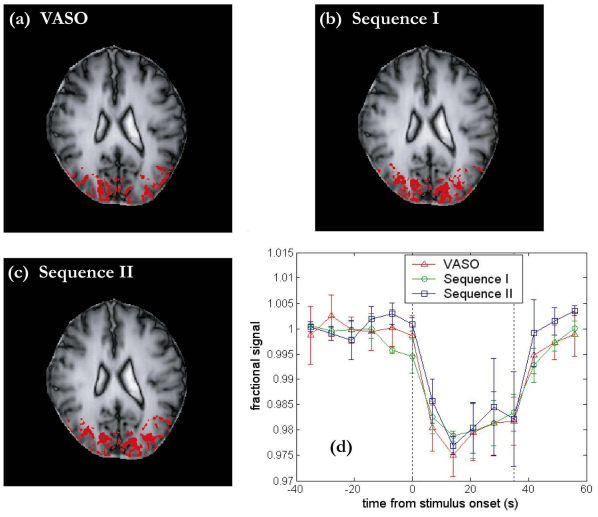

Fig.2. fMRI activation maps (a-c) from one subject for VASO-TSE, sequence I and II, respectively. (d) is the time course averaged over all subjects (n=5). The vertical lines indicate the start and end of the stimulus.

(1) Lu, et al. MRM 2003;50:263. (2) Balaban & Ceckler Magn. Reson. Q. 1992;2:116. (3) Pike, et al. MRM 1992;25:372. (4) Donahue, et al. MRM 2006;56:1261.
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