Asymmetric magnetization transfer effects for perfusion imaging in transient ischemic brain tissue in rats

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Target Audience: Researchers interested in stroke animal models and perfusion imaging.

Purpose: Post-ischemic hyperperfusion was observed in transient ischemic tissue 48 hours after middle cerebral artery occlusion (MCAO) using the continuous arterial spin labeling (CASL) method [1-3]. In arterial spin tagging approaches, cerebral blood flow (CBF) quantification differed between polarities of neck labeling gradient. The CBF difference was caused by asymmetric magnetization transfer (MT) effect especially in a single radio-frequency coil [4]. Asymmetric MT effects have not been investigated in the post-ischemic hyperperfusion studies[1-3]. Several papers described the MT effect was negligible in a two-coil system consists of a small labeling coil in neck position[3-5]. However in our experience, the asymmetric MT effect was observed even in a two-coil system. We have investigated the asymmetric MT effect in CASL with the two-coil system for transient ischemic tissue of MCAO model rats.

Methods: Thirty-eight male Sprague-Dawley rats (240-350 g) were used. Sixty minutes of transient ischemia was induced by occluding the left middle cerebral artery with embolic thread. The rats were set in the 4.7-T MRI spectrometer (Unity Inova; Varian, USA) in 24, 48 and 72 hours after reperfusion. Anatomical T_2 weighted spin-echo images were acquired and T_1 maps were calculated from the Look-Locker sequence acquired with 10 inversion times. CASL was performed using a two-coil system with labeling neck coil and quadrature brain surface coil (Rapid Biomedical, Germany). CASL image was acquired with a gradient echo sequence (TR/TE =8/4 ms, post delay = 400 ms). Asymmetric ratio is defined as $(M_{label}^{+} - M_{ref}^{+})/(M_{label}^{-} - M_{ref}^{-})$, where M_{label} is the brain tissue signal acquired by brain surface coil 3 seconds after RF irradiation at a labeling position for neck coil and M_{ref} is the signal with RF irradiation of control position. Superscripts of + and – indicate the presence of labeling gradient of 1 and –1 Gauss/cm at RF irradiation, respectively. CASL CBF was calculated as $\lambda/T_{1b} \times (M_{label} - M_{ref})/(M_{label} + (2\alpha - 1)M_{ref})$, where λ is the blood-brain partition coefficient and α is the efficiency of labeling[2,3,5]. λ and α was taken to be 0.9 ml/g and 0.9, respectively[4,5]. Measured T_1 maps are used for T_{1b}. Paired t-test was used to compare among asymmetric ratios and CBF values. Statistical significance was set at $P < 0.05$.

Results: Typical images of post-ischemic hyperperfusion are shown in figure 1. CASL CBF with minus polarities of the labeling gradient was higher than with plus polarities. The difference between two CBF images indicates the existence of asymmetric MT effect even in a two-coil system. Asymmetric ratios of left ischemic caudate-putamen (I-Cpu) were higher than those of healthy right Cpu (N-Cpu). Temporal profiles of asymmetric ratio after reperfusion are shown in figure 2. Asymmetric ratios are less than 1.0 in all rats and time points. The ratio in I-Cpu was significantly higher than that of N-Cpu in every time point. The ratio in N-Cpu and I-Cpu are 0.73±0.16, 0.89±0.13, respectively. Figure 3 shows the temporal profiles of CBF after reperfusion. CBF was calculated as the mean value between two labeling gradient polarities for compensation of the asymmetric MT effect[4]. CBF at 48 hours after reperfusion was significantly higher than at 24 and 72 hours.

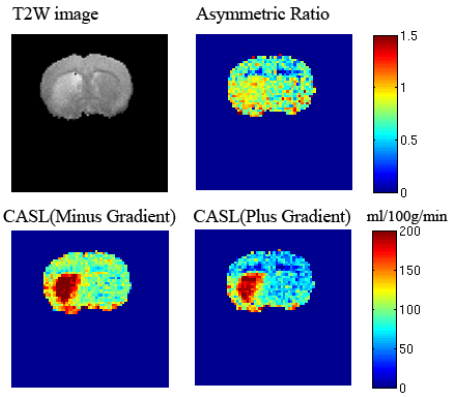

Figure 1. Typical image of 48 hours after reperfusion.T2 weighted, asymmetric ratio image and CBF image with two different labeling gradient polarities are shown.

Discussion: CBF images with the two-coil system are affected by asymmetric MT effect and compensation of the MT effect should be required. This systemically smaller value in asymmetric ratio may be the results of asymmetric frequency response of the RF coil or imperfection in the gradient. Asymmetric ratio differences between I-Cpu and N-Cpu might be the result of macro molecular difference in ischemic tissue.

Conclusion: Asymmetric MT effect in CASL CBF must be compensated even though the two-coil system. After compensation of the MT effect, post-ischemic hyperperfusion at 48 hours after reperfusion still appear.

References: 1. Wang et al., JCBFM 2002 ; 22 : 253-262, 2. Nakamura et al., Proc IEEE EMBS 2008 ; 30 : 839-842, 3. Shen et al., JCBFM 2011 ; 31 : 2076-2085, 4. J Pekar et al., MRM 1996; 35: 70 – 79, 5. AC Silva et al., MRM 1995; 33: 209 – 214

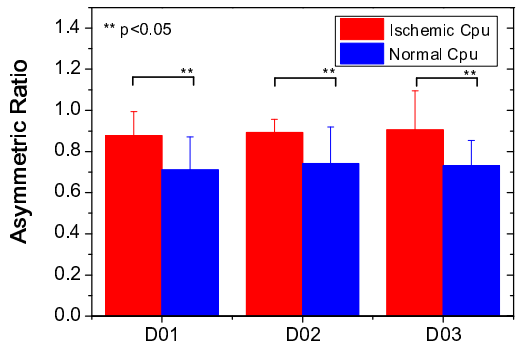

Figure 2. Changes in asymmetric ratio after reperfusion. Mean and SD value from 38 rats in left ischemic and right normal Cpu are shown.

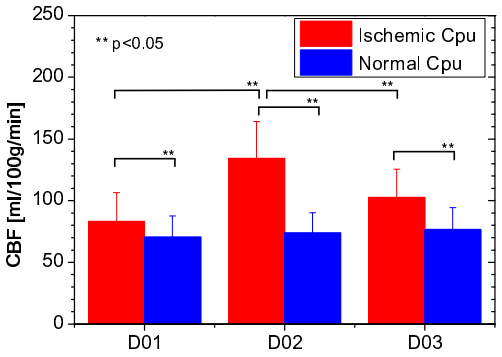

Figure 3. Changes in CBF after reperfusion. CBF is compensated with asymmetric MT effect. Mean and SD value from 38 rats in left ischemic and right normal Cpu are shown.