Measurement of Dynamic CBV Changes During Brain Activation Using A Tissue Suppression Method

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Synopsis

Inversion recovery (IR) pulse sequence with inversion time (TI) that suppressed tissue signals was proposed to estimate the regional cerebral blood volume (CBV) change in this study. The detected contrast-to-noise ratio (CNR) was 1.0 ± 0.19 at 1.5T, which was approximately two times larger than that of the previously published method with blood signal suppression. The mean CBV change during steady-state brain activation was estimated to be 31%, assuming 5% resting CBV and 8.1% cerebrospinal fluid (CSF) volume fraction.

Introduction

Recently, several approaches have been addressed to detect CBV change dynamically. Among these approaches, IR method, such as VASO [1], adopts T1 characteristics and detects the CBV change non-invasively. However, VASO showed low CNR in functional imaging performance. In this study, we changed TI and demonstrated an alternative IR method with higher CNR. Furthermore, CBV changes were also estimated by assuming both resting CBV and CSF volume fraction.

Methods

It was assumed that only three compartments exist in the voxel: blood, tissue, and CSF, with spin-lattice relaxation time (T_1^b T_1^t and T_1^c): 1350, 880, and 4300 msec respectively [1, 2]. With non-selective inversion recovery (NSIR) sequence and inversion time that suppress tissue signal, the NSIR signal will be expressed as sum of blood and CSF signal, as shown in Eq.[1]. Besides, assuming CSF volume fraction does not change during activation, the signal change can be expressed as Eq. [2]:

$$S(TI) \approx v \cdot M_b(TI) \cdot e^{-TE \cdot R^*_{2(blood)}} + v_{CSF} \cdot M_{CSF}(TI) \cdot e^{-TE \cdot R^*_{2(CSF)}} \quad [1]$$

$$\frac{\Delta S}{S} = \frac{\left[v^{actv} - v^{rest}\right] \cdot M_b(TI)}{v^{rest} \cdot M_b(TI) + v_{CSF} \cdot M_{CSF}(TI)} \quad [2]$$

where v^{actv} represents CBV in active state, v^{rest} represents CBV in resting state, v^{CSF} is the CSF volume fraction, TE is the echo time, $R_{2\,(blood)}^*$ and $R_{2\,(CSF)}^*$ is the blood and CSF relaxation rate. Assume that R_2^* effect can be neglected with shortest TE. According to Eq.[2], NSIR signal change can be reflected on CBV change.

Experiments were performed by 1.5 T Magnetom Vision (Siemens, Erlangen, Germany). Block-designed visual stimulation task with 8 Hz flashing black and white checkerboard (27 sec on, 27 sec off, 6 blocks) were applied to 3 subjects by LCD goggle. Single slice functional images were scanned by NSIR sequence with 128 x 128 matrix size, 211 x 211 mm field of view, 8 mm thickness, and TR/TE equal to 4500/9.3 msec. TI of 610 msec (TI_1) was used for suppressing tissue compartment and, for comparison, TI of 920 msec (TI_2) was also performed in experiments. Data were temporally smoothed by 3-point symmetric Hanning window and analyzed by cross-correlation analysis with threshold 0.2, cluster size 3, excluding large vessel effects. CBV changes were estimated by Eq.[2] with v^{rest} assumed to be 5% and v^{CSF} roughly evaluated by 8.1% using Eq.[1], computed by signal intensities of large vessel and CSF in axial image [3].

a. b.

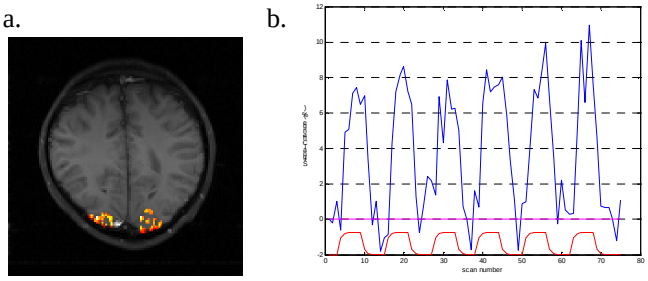

Figure 1:
a) Visual activation map for NSIR sequence with TI equal to 610 msec, which was overlaid on high- resolution anatomical image. b) Time Courses of neural activation of subject #2, 78 scans. Red curve is the reference scan and magenta curve represents the baseline.

	SNR	Signal change (%)	CNR
TI_1 (610 ms)	17.16 ± 1.79	5.83 ± 1.05 %	1.00 ± 0.19
TI_2 (920 ms)	32.76 ± 4.31	1.49 ± 0.27 %	0.48 ± 0.08

Table 1:
Comparison of SNR, signal change and CNR between TI_1 and TI_2

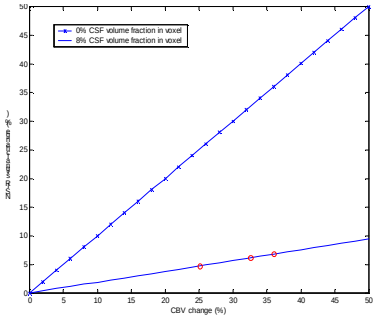

Figure 2:
Relationship between CBV change and NSIR signal change.

Results

3 subjects had brain activations in visual area with 6.73%, 6.08%, and 4.68% signal change respectively. Figure 1 shows the result of second subject: figure 1a is the activation map overlaid on high-resolution T1 image and figure 1b is the mean time course of activated voxels. Comparison of different inversion time is presented in Table 1. Because most tissue signals are suppressed by TI_1, signal-to-noise ratio (SNR) of TI_1 is smaller than that of TI_2. However, strong signal change of TI_1 is detected; resulting in CNR is two times larger than that detected by TI_2. Figure 2 shows the relationship between estimated CBV change and the NSIR signal change. Cross and solid lines represent the without considering CSF volume fraction and consider 8.1% CSF volume fraction in the voxel. Comparatively, estimated CBV changes are calculated by 36.11%, 32.61%, and 25.14% (red circles), which fall into a reasonable range when v_{CSF} is considered to be 8.1%.

Conclusion & Discussions

A preliminary tissue suppression method was proposed in this study. Comparing with VASO method, which utilized blood-nulling TI, the tissue suppression method has stronger signal change and better CNR. Furthermore, when considering 8.1% CSF volume fraction, the estimated CBV changes locate in a reasonable range. Nevertheless, low SNR is the main drawback of the method and the resting state physiological parameters should be assumed in CBV changes estimation. Further studies are needed to prove the accuracy and specificity of the method.

References

[1]. Lu H et al., Magn Reson Med 2003; 50; 263-274
[2]. Donahue KM et al., Magn Reson Med 1994; 32; 66-76
[3]. Lu H et al., NeuroImage 2002; 17; 943-955