Measurement of Transient State Cerebral Blood Volume Change with Compensation for T2 Variation

J-J. Wang[1], H. Liu[1], Y-C. Chen[1]

[1]School of Medical Technology, ChangGung University & ChanGung Memorial Hospital, Taipei, Taiwan

Introduction

Cerebral Blood Volume (CBV) changes at transient state was measured by a T2 weighted inversion prepared Spin Echo EPI sequence(1) using an Event Related fMRI(ER-fMRI) paradigm. Flow nulling gradients were applied to selectively attenuate the blood signals. CBV changes due to 1-s visual stimuli during brain activation were dynamically measured with a temporal resolution of 1s. The maximum CBV change and averaged time courses were calculated from two normal volunteers.

Theory

The accuracy in the estimation of CBV played an important role in the estimation of the measurement of $CMRO_2$, which is essential in the understanding of the haemodynamic response. CBV changes were usually estimated from the cerebral blood flow (CBF) changes using a power law determined in the steady-state as $cbv = cbf^{0.38}$ (2). However, the relationship is unclear during transition period. Diffusion weighting gradients have been proposed to selectively attenuate the flow signal in the blood volume and have been used for the measurement of cerebral blood volume (CBV) in steady-state (3-5). The signal change during functional activation can be modeled as the volume change with a compensation factor for T2 as in Eq. 1, where ΔS was the signal difference between selectively attenuated and non-attenuated images in activated (a) and resting (r) state, V was the corresponding CBV, $\Delta R2$ was the change in the transverse relaxation rate.

$\Delta Sa/\Delta Sr = (Va/Vr)\, e^{-\Delta R2 \cdot TE}$ [1]

To allow for the measurement of blood volume without the requirement to correct for the effects of T2 in blood, a T2 FLAIR SE-EPI sequence with good compensation for the functional $\Delta R2$ changes from BOLD related effects was developed. In this study, the blood volume change was estimated during activation and resting states respectively, which allows us to estimate the changes during transition period. Because T1 was relatively insensitive during functional activation, TI was chosen so that the functional T2 change was compensated over a range of 63 to 104 ms. Appropriate diffusion weighting was added to selectively attenuate the CSF and blood signal.

Methods

Two normal subjects (aged 24 and 22) were imaged on a 1.5T Magnetom Vision MR scanner (Siemens, Erlangen, Germany). The pulse sequence consists of a T2-Flair prepared Spin-Echo EPI with/without diffusion weighting gradients. The in-plane resolution was 4 mm * 4 mm, a slice thickness of 8 mm and flip angle 90°. The FOV is 256mm. Other imaging parameters included TR/TE/TI/τ =2000 ms/43 ms/ 89.4 ms/ 25.4 ms. One pair of unipolar diffusion weighting gradients (duration of 10 ms and strength of 22 mT/m) was placed on both sides of the refocusing 180° RF pulse, leading to a b-factor of 36 s/mm^2.

The event-related fMRI was performed throughout the acquisition. The stimulus includes an 8-Hz flashing checkerboard of 1 s duration followed by a fixation crosshair of 17 s. Twenty-one repeated trials were presented during an 598 s measurement with flow nulling gradients. The experiment was then repeated with 1 s time shift. Data from acquisitions with and without time shift were later interleaved to increase the temporal resolution to 1 s per time point. The whole procedure was repeated again for acquisitions without the flow nulling gradients. Images with flow nulling gradients were scaled by a factor of e^{bD}, with D assumed as $0.9*10^{-3}$ mm^2/s and then subtracted from the corresponding images without flow nulling gradients. The difference images were then smoothed by a Gaussian filter spatially (FWHM = 8mm) and temporally (2 s). Activated voxels were selected by correlation of the resultant images with a gamma variate function. Voxels survived the uncorrected t-test ($t > 3.428$, $P < 0.005$) was regarded as activated.

An additional 4 runs of BOLD based fMRI with block design were acquired with a GRE-EPI sequence to confirm the area of activation. Each block consists of an 8-Hz flashing checkerboard with duration of 30 s and a fixation crosshair of 30 s. The parameters of acquisition are TR/TE/Θ= 2000 ms/60 ms/ 90° with the same spatial resolution. Activated voxels survived the uncorrected t-test ($t > 2.871$, $P < 0.005$).

Results

Figure 1 shows the activated areas from significant CBV changes attached on a T2-Flair image with flow nulling gradient in one subject. The area of activation was well within the activated area from BOLD fMRI. The time courses from the activated voxels in ER-fMRI were then averaged. Figure 2 shows the mean percentage CBV changes averaged from both subjects after normalization.

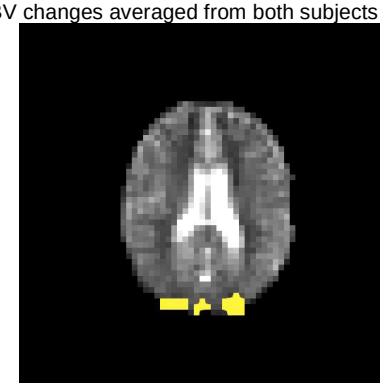

Figure 1 Activation Map from CBV change attached on a T2-Flair image with flow nulling gradient

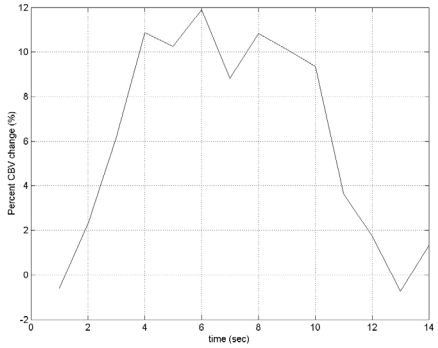

Figure 2 Averaged time course

Discussion

Our results indicate that the measurement of CBV changes due to brief visual stimulation is possible in a T2-Flair SE-EPI sequence, which provides good T2 compensation. By using flow nulling gradients during an ER-fMRI experiment, the normalized temporal signal of CBV changes began to increase immediately after the visual stimulus and reached a maximum at approximately 6 s to 8 s after the event. The maximum change in CBV is 11.9 %. A delay in returning to the baseline was observed, which occurred between 12 s and 14 s. This finding is consistent with current understanding of post-stimulus undershoot in BOLD signal. Our preliminary result proved useful in the further understanding of the haemodynamic response.

References

1. Wong, E.C. et al., Proc. 5th ISMRM,.p.372 (1997) 2. Grubb, R. et al., Stroke 5: 630-639 (1974). 3. Alsop, D.C. et al., Proc. 7th ISMRM, p.1761 (1999) 4. Le Bihan, D.et al., Radiology 168:497 (1988) 5. Liu, T.T. et al, Proc. 8th ISMRM,.p.53 (2000)