The b=0 dependence of diffusion-based functional MRI signals to measure neuronal activations

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Introduction: Using diffusion weighted image (DWI), people investigated in brain activations using diffusion-based functional MRI (fMRI) [1] that has an advantage over blood oxygen level-dependent (BOLD)-based fMRI because functional information with diffusion-based fMRI can obtain in a cellular level rather than an intravascular level [2]. This diffusion-based fMRI signal is notably different from the BOLD fMRI signal, especially for its much faster response to brain activation both at onset and offset [3]. However, those previous studies were obtained in DWI data for both without diffusion gradients (b0) and with diffusion gradients (DWI) in each time point during both stimulation and baseline conditions. Therefore, the previous sequence can increase dynamic scan duration for each stimulation and may be inefficient to measure hemodynamic changes. Moreover, there was no study to investigate the b0 effect in diffusion fMRI. The objective of this study, therefore, was to investigate b0 effects on neuronal activations based on diffusion-based dynamic fMRI with improving the dynamic scan duration.

Materials and Methods:

Pulse Sequence Design: To obtain the diffusion-based dynamic fMRI, a single-shot spin echo sequence was modified with a trace-weighted DWI sequence [4]. A sequence was designed to obtain trace values at a time as putting diffusion-sensitizing gradients on three axes diagonally. One DWI with b=0 s/mm^2 (b0_b) was obtained during the first baseline scan and then 107 DWIs with b=600 s/mm^2 were imaged with altering the baseline and the stimulation. Finally, another DWI with b=0 s/mm^2 (b0_a) was again obtained during the last stimulation scan. Visual stimulation was performed with using the black-white checkerboard paradigm. The duration of the image acquisition was 6 min 28 sec. This paradigm was run on **16** young healthy volunteers (7 males, 9 females; mean age: 26.38) at a 3T MRI system (Achieva, Philips Medical system). In addition, BOLD fMRI data were also obtained compare it to diffusion-based fMRI.

Image Analyses: ADC maps for all time points were obtained with two different ways: 1) ADC_b was obtained with using the b0_b image obtained during the first baseline scan and 2) ADC_a was obtained with using the b0_a image obtained during the last activation scan with MatLab software (Math-works Inc., Natick, MA, USA). Activation maps for each subject were obtained using comparisons between the baseline and the stimulation for BOLD, DWI, ADC_b, and ADC_a data. One sample t-test was used to investigate voxel-wised average over subjects.

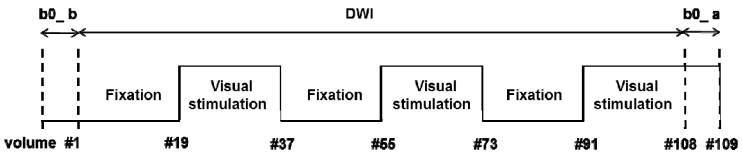

FIG.1. The fMRI paradigm course diagram for the diffusion-based dynamic fMRI sequence.

Results: Fig.2 shows results for activated brain regions during the visual stimulation. Activation areas with BOLD data were largely distributed at the occipital lobe. However, activated areas of DWI, ADC_b, and ADC_a data were smaller than those of BOLD fMRI data. With DWI data, areas in the left lingual gyrus and the right lingual gyrus of the occipital lobe were activated and activated areas of ADC_b and ADC_a data were in the right cuneus and left the cuneus of the occipital lobe. The ADC_b in the right cuneus and left the cuneus of the occipital lobe were 2.78x10^3 and 2.85 x10^3 mm^2/sec and the ADC_a in the right cuneus and left the cuneus of the occipital lobe were 2.74 x10^3 and 2.67 x10^3 mm^2/sec. In comparison with ADC_b and ADC_a, both were showed similar deactivated and activated areas. The activated areas of DWI, ADC_b, and ADC_a did not match the activated areas of BOLD.

Discussions: We developed the diffusion-based sequence to efficiently obtain b0 and DWI during stimulations. It has an advantage to reduce scan time by not obtaining b0 in each time point. There were no differences of activated areas between two ADC values. In addition, activation areas of DWI and ADC were not similar to those of BOLD. Previous studies showed that the ADC changes during neuronal activation [5] and ADC value during neuronal activation increases [6] or decreases [7] [8]. Our results showed both decreased and increased ADC values during the visual stimulation. Our study may reinvestigate with a high b-value to increase observation of water diffusion in activated brain tissues [3].

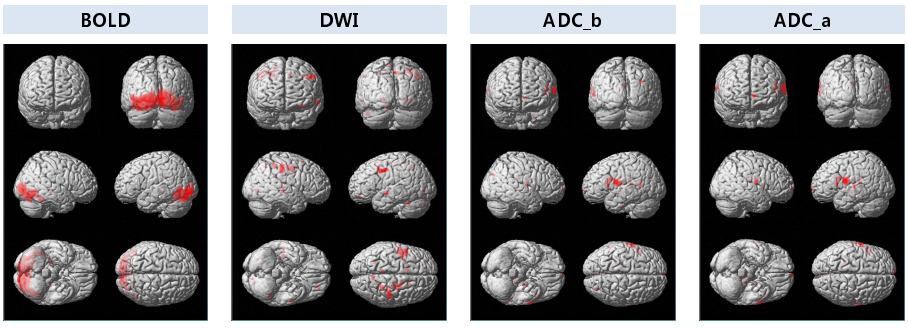

FIG. 2. Results of BOLD, DWI, ADC_b, and ADC_a for activated brain regions for visual stimulation over 16 subjects.

Conclusion: In this study, we designed a diffusion-based fMRI sequence to investigate b0 effect on brain activations during visual stimulation. There were no differences of activation areas between two different b=0 images. Therefore, it can be obtained only one b0 without obtaining in each time point.

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