Towards T2 Weighted fMRI of the Whole Brain at Ultra-High Fields

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Introduction/Synopsis

Spin Echo (SE) BOLD based Functional Magnetic Resonance Imaging (fMRI) is less sensitive to the extra vascular response from larger vessels and, at ultra-high magnetic fields, is less sensitive to blood contributions to functional mapping signals. Hence, SE fMRI is less contaminated by contributions which may originate far from the actual site of neuronal activation than Gradient-recalled Echo (GE) fMRI. A major disadvantage of SE fMRI signals is that the mapping signals are inherently weak. However, they increase supralinearly with magnetic field and attain usable magnitudes at ~7 Tesla or above. Thus, SE fMRI at ultra-high magnetic fields provide a high contrast-to-noise ratio (CNR) and high spatial accuracy method for functional mapping (see for instance [1], [2]). Specific absorption rate (SAR) considerations, however, have been a limiting factor in pursuing multi slice SE Echo-Planar Imaging (EPI) at ultra high field strengths. In this study, a slab wise T_2 magnetization preparation followed by a multislice series of GE EPI readouts is presented. This method reduces SAR significantly. Robust BOLD responses are observed.

Methods

Two normal subjects participated in this study. The experiments were performed at a 7T, 90cm bore system consisting of a Magnex magnet and a Varian console. A surface rf-coil assembly consisting of large transmit and small receive coils was used. The visual paradigm consisted of 10 blocks. Within each block a flashing red checker board was presented for 30s followed by a 30s resting period. The total duration was about 10 minutes. Each 30s period consisted of 5 acquisitions. Each acquisition consisted of the same T_2 prepared 30mm slab in the visual cortex (see Fig. 1), and was subsequently read out by 10 interleaved GE EPI slices of 2mm thickness each. (FOV=20.0x12.0cm^2; matrix=128x64; single shot acquisition; 90 degree pulses; echo time for the preparation slab was 55ms; echo time for the GE EPI readout employing half-Fourier was 6.65ms to center k-space point. TR in the multi slice GE EPI train was ~ 23.5ms per slice leading to 235ms for the 10 slice acquisition following each T_2 preparation module). For comparison, a dataset with the GE EPI multi slice readout without the T_2 preparation module was obtained. Identical readout was played for the prepared and non-prepared acquisitions. To study inflow effects for this sequence based fMRI, a thick (120mm) slab was prepared for one of the studies and the multi slice readout was compared to that of the 30mm thick slab. In addition, the apparent decay time for the weight of the preparation module was measured by varying, TE_{Slab}.

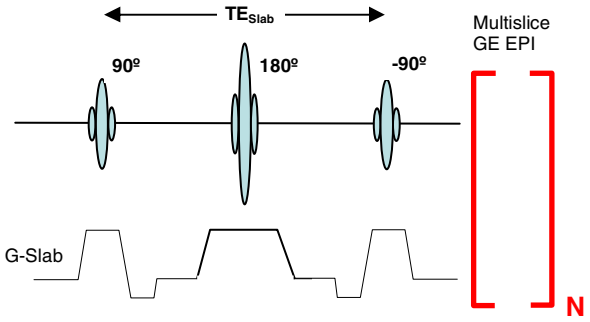

Fig.1 A schematic view of the slab selective T_2 magnetization preparation, consisting of a 90º pulse followed by a refocusing 180º pulse and a -90º to flip back the magnetization along the z axis. Then N slice selective excitation pulses are applied, each followed by GE EPI readout.

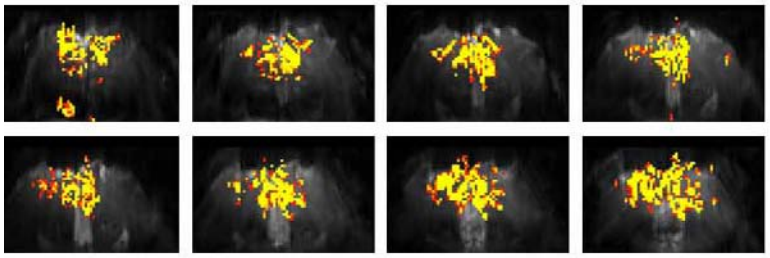

Fig.2 Activation maps from one volunteer using T_2 magnetization prepared multi slice GE EPI are shown. Only 8 slices out of the total 10 acquired are presented. Voxels with p-values≤.00063%, corresponding to 4σ, and cluster size threshold of 6 are highlighted. The average activation, ΔS/S, measured for both volunteers was (4.78 ± 0.31) %.

Results and Discussion

Significant BOLD responses were detected (see Fig. 2). The activation was measured to be (4.78±0.31) %. This compares to an activation of (2.53±0.03) % for the multi slice GE EPI without the T_2 weighting preparation module. The quoted errors reflect the variance between the two subjects. The T_2 prepared approach produced more diffuse activation that was clearly less associated with blood vessels or intrasulcul space. GE contributions to the overall mapping signals in this sequence can be further reduced by use of parallel imaging (PI) techniques to reduce the time of k-space coverage. PI methods would also allow for a larger number of slices to be covered after a single T_2 preparation.

Power deposition, compared to a multi slice Spin Echo sequence executed with 90 and 180 degree pulses, was reduced by ~3 fold for 10 slices (for the same total data acquisition time). Further reduction of SAR relative to normal SE acquisition would be achieved for more slices acquired subsequent to a single T_2 preparation; this can be achieved without prolonging the total time spent in the multislice GE EPI acquisition by implementing PI techniques. The apparent T_2 value measured by arraying the TE_{slab} in the preparation module was 55ms (R^2=0.99), in excellent agreement with values for grey matter found in the literature (see for instance [1]). A comparison between the thick and thin slab prepared fMRI, that was done for one of the subjects, yielded an average activation, ΔS/S, of (4.52±0.07) % with 2569 activated pixels for the thinner slab versus (4.15±0.06)% with 2691 active pixels for the thick slab, suggesting negligible inflow effect.

This approach, together with additional increases in speed and/or resolution expected from a straight-forward implementation of this technique in conjunction with parallel imaging, opens the door towards expanding the use of SE weighted fMRI for whole brain studies.

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