T2 weighted fMRI with Whole Brain Coverage at Ultra-High Fields

J. Ritter[1], E. Auerbach[1], G. Adriany[1], and K. Ugurbil[1]

[1]Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States

Introduction/Synopsis

There exists a synergy between Spin Echo (SE) fMRI and Ultra-High Fields; inherently weak SE mapping signals attain usable magnitude at 7 Tesla or above and the accuracy of functional maps obtained with SE increases (see for instance [1], [2], [3]). 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 magnetization Preparation for Functional Imaging with a T_2 weight (SPIF-T_2) [3] is used to address these SAR issues. Parallel Imaging (PI) methods with a one-dimensional reduction factor of four, a half-Fourier technique and a sixteen-channel geometrically adjustable ("flex") volume coil [4] are used to allow for whole brain coverage while maintaining short acquisition times, necessary to keep Gradient Echo (GE) contributions small. 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 Siemens console. 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 axial slab going through the visual cortex (see Fig. 1), and was subsequently read out by 10 interleaved GE EPI slices of 2mm thickness each.

A sixteen-channel geometrically adjustable volume coil was used. (FOV=19.2x19.2cm^2; matrix=128x128; single shot acquisition; 90 degree pulses; echo time for the preparation slab was 55ms; echo time for the EPI readout employing half-Fourier was 9.0ms to center k-space point. TR in the multi slice EPI train was ~ 33.4ms per slice leading to 334ms for the 10 slice acquisition following each T_2 preparation module; a 12.2ms fat suppression module in front of each slice is included). For comparison, a dataset with the EPI multi slice readout without the T_2 preparation module was obtained for one of the subjects. Identical readout was played for the prepared and non-prepared acquisitions. To study inflow effects for this sequence based fMRI, a thick (100mm) 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 had previously been measured by varying, TE_{Slab} [3], yielding 55ms, in excellent agreement with values for grey matter found in the literature (see for instance [1]).

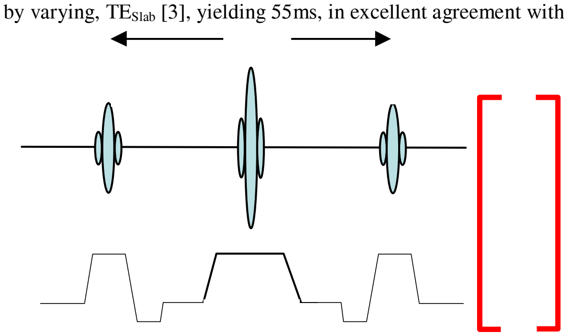

Fig.1 A schematic view of the slab selective T_2 magnetization preparation, consisting of a 90º pulse followed by a refocusing 180º pulse and a -90º to flip back the magnetization along the z axis. Then N slice selective excitation pulses are applied, each followed by EPI readout.

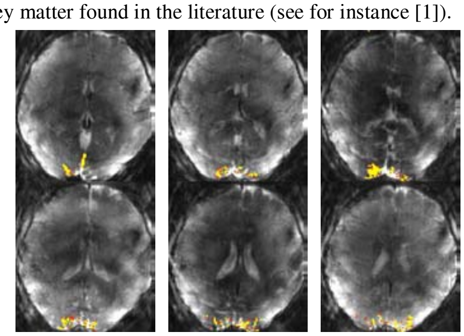

Fig.2 Activation maps for one volunteer using T_2 magnetization prepared multi slice EPI implemented with parallel imaging are shown. Only 6 slices out of the total 10 acquired are presented. Voxels with p-values≤.00006%, corresponding to 4σ, and cluster size threshold of 14 are highlighted.

Results and Discussion

Significant BOLD responses were detected for the two subjects using SPIF-T_2 (see Fig. 2 for the activation maps obtained with parallel imaging). The average activation, ΔS/S, was measured to be (10.37±.16) %. This compares to significantly lower activation of (7.31±.13) for the multi slice EPI without the T_2 weighting preparation module. The number of activated pixels, however, is significantly lower for the T_2 prepared case. This can be explained with an overall reduction in SNR due to the T_2 weighting of the preparation module.

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 (10.31±.22) % with 945 activated pixels for the thinner slab versus (10.38±.23) % with 901 active pixels for the thick slab, suggesting that any inflow effect is very small indeed.

Power deposition, compared to a multi slice Spin Echo sequence executed with 90 and 180 degree pulses, is reduced by ~3 fold for 10 slices (for the same total data acquisition time).

The implementation of SPIF-T_2 with parallel imaging techniques has been demonstrated. The current implementation still suffers from a significant GE contribution due to the fact that the EPI acquisition is not short enough and there exists a 9 ms delay to the center k-space point after excitation. This limitation is imposed by use of a body gradient in the current study. Changing to a head gradient system from the currently used body gradient system and further optimizations of this acquisition method can reduce GE contributions to the overall mapping signals in this sequence further as the time of k-space coverage is reduced; This opens the door towards expanding the use of SE weighted fMRI from covering a single slab to a slab wise coverage for whole brain studies.

	W T_2 Preparation Module		W/O T_2 Preparation Module	
Subject #	Average Activation ΔS/S in [%]	# of activated pixels	Average Activation ΔS/S in [%]	# of activated pixels
1	10.31±0.22	945	7.31±0.13	1796
2	10.42±0.22	769		

Tab. 1 Average activations, ΔS/S, and # of activated pixels W and W/O the T_2 preparation module. Identical multi slice EPI readout was played for the prepared and non-prepared acquisitions.

	30 mm Slab Thickness		100 mm Slab Thickness	
Subject #	Average Activation ΔS/S in [%]	# of activated pixels	Average Activation ΔS/S in [%]	# of activated pixels
1	10.31±0.22	945	10.38±0.23	901

Tab. 2 Average activations, ΔS/S, and # of activated pixels for the thin (30 mm) and thick (100 mm) slab prepared fMRI.

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