A Novel T2* GRASE single-shot 3D sequence for BOLD Imaging

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The Gradient and Spin Echo (GRASE) pulse sequences has been used primarily for T2 weighted imaging, with the spin echoes of the CPMG sequence utilized for the center of k-space. While to date, T2 contrast has been a fundamental feature of GRASE, it is possible to obtain T2* and BOLD signal contrast mechanisms in GRASE by shifting the central region of k-space from spin echoes to gradient echoes in the echo train. The purpose of this work was to obtain T2* and BOLD contrast in a single-shot 3D GRASE sequence (1).

Method: A technique proposed to achieve BOLD contrast in GRASE images is shown in **Fig 1**. For each 3D k-space partition, ko and the positive side of 2D k-space (k+) are shifted to an earlier time between the 180° refocusing pulses while the negative side (k-) is wrapped into the later time period of the RF pulse interval. Thus the central regions of k-space are positioned onto gradient echoes for T_2* weighting which increases BOLD contrast in images. The phase encoding pulses are played out to move the trajectory in the 2D k-space away from the positive edge to the negative edge of k-space or vice versa (refer to k-space diagram in Fig **1**). A potential disadvantage of this approach is that it produces a discontinuity of T2* dependent magnitude (M) and phase shifts in k-space, however with the discontinuity at a lower energy non-central region of k-space rather than at k_0, potential artifacts should be greatly reduced.

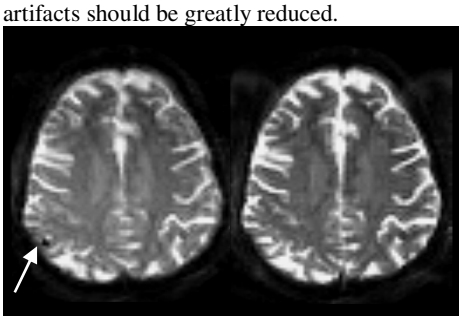

Fig. 2 1 of 24 slice in 3D volume (**left**) T2* GRASE (**right**) T2 GRASE

Experiments were performed at 1.5T and 3T in 3 normal individuals, following institutional guidelines. Time course data was obtained with a unilateral left hand grip blocks vs right hand grip blocks, paradigm. At 1.5T the time course data was obtained with 4 blocks of 10 3D images, alternating right and left hand gripping, while at 3T the same unilateral hand grip paradigm was repeated with 6 blocks of 15 3D images. Imaging parameters were as follows: TR/2500ms, TE/41.5ms, matrix size 64x64x24, FOV 225x225x120 mm^3, BW/2005Hz, 16 echo shift, and slice thickness/5 mm.

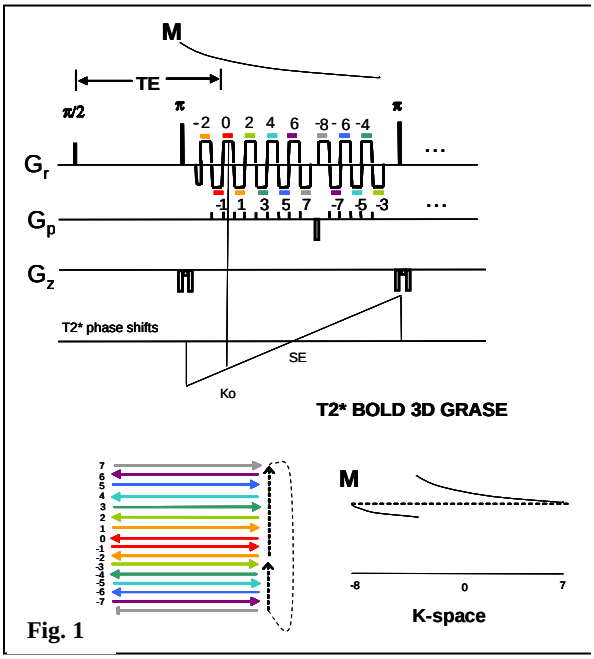

Fig. 1

Results

Results using a T2* weighting of 11 msec offset of ko from the SE position, did not cause significant image artifacts, **Fig 2**, compared to 3D images conventionally encoded with a SE position of ko. The T2* image, Fig.2, shows a small black focus of susceptibility dependent signal loss, hemosiderin in the subarachnoid space, which was not seen in the conventional T2 image. There were no significant artifacts observable from discontinuity in k-space encoding.

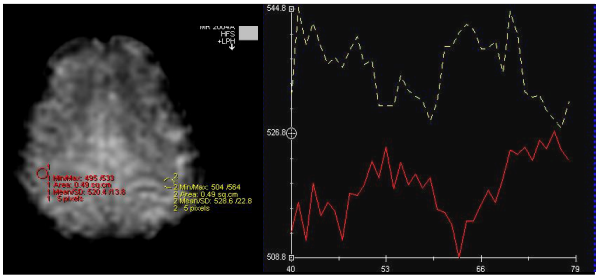

Fig 3 (**left**) fMRI time course data shows the alternating signal between the right (red) and left (dashed yellow) M1 motor cortex regions, at 1.5T.

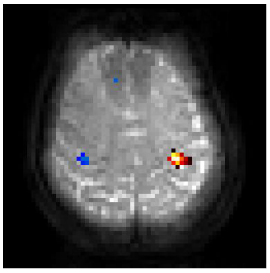

Fig. 4 (**right**) T statistic map thresholded at 3.5 with both left and right M1 regions showing high significance (blue deactivation), at 3T.

The SNR in grey matter was 80 at 1.5T and 234 at 3T. The T2* GRASE images had expected regions of signal drop out in high susceptibility regions near the paranasal sinuses, whereas signal drop out was not present in the T2 weighted images.

Discussion: A novel k-space trajectory in GRASE has achieved T2* weighted contrast without requiring preparation pulses, or violation of the CPMG condition. Thus the full signal magnetization was utilized without spoiling, as there are no stimulated echo magnetization related artifacts (2,3). The new T2* variants of 3D GRASE provided BOLD contrast and may be useful when developed and optimized beyond these proof of concept experiments. With the single-shot 3D BOLD images, brain activity is recorded simultaneously in all slices of the 3D volume, which may be advantageous for functional connectivity experiments and physiologic noise would be coherent in all slices. Another potential application is to utilize the same 3D GRASE readout for T2* BOLD, VASO and ASL CBF maps for accurate co-registration in calculating metabolic and hemodynamic parametric maps. While presented in 3D GRASE imaging, the T2* methodology could be used for 2D GRASE imaging as well.

Conclusion: T2* contrast has been obtained in the GRASE pulse sequence by reordering phase encoding in the echo trains.

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References: **1**) Gunther et al, MRM, 2005, **54**(2): p. 491-498. **2**) Jovich J et al, MRM, 1998, 39(6):970 9., **3**) Jovich J et al, MRM, 1999, 41(5):871-6.