Making High Resolution T2 and T2* Maps Through the Use of Accelerated Gradient-Echo Asymmetric Spin-Echo (GREASE) Pulse Sequences

D. L. Shefchik[1], A. S. Nencka[1], A. Jesmanowicz[1], and J. S. Hyde[1]
[1]Biophysics, Medical College of Wisconsin, Milwaukee, WI, United States

Introduction:

The gradient-echo asymmetric spin-echo pulse sequence (GREASE) allows multiple images to be acquired in each excitation [1]. The original purpose of this technique was to obtain true T2 and T2* maps. In order to obtain these maps, at least three images with differing effective echo times (ETE) have to be taken per pulse. In the acquisition of the three images with the GREASE technique, the signal sequentially gets worse with each image due to being farther out on the T2 decay curve. This problem is amplified when moving from 64x64 images to 96x96. In order to reduce this image decay three sequence modifications were implemented to decrease the readout time of standard GREASE and maintain more signal in the second and third images. The modifications included partial k-space GREASE [2], generalized autocalibrating partially parallel acquisitions (GRAPPA) Grease [3], and partial k-space GRAPPA GREASE. The sequences are implemented and compared to the original GREASE sequence to determine the best technique.

Theory:

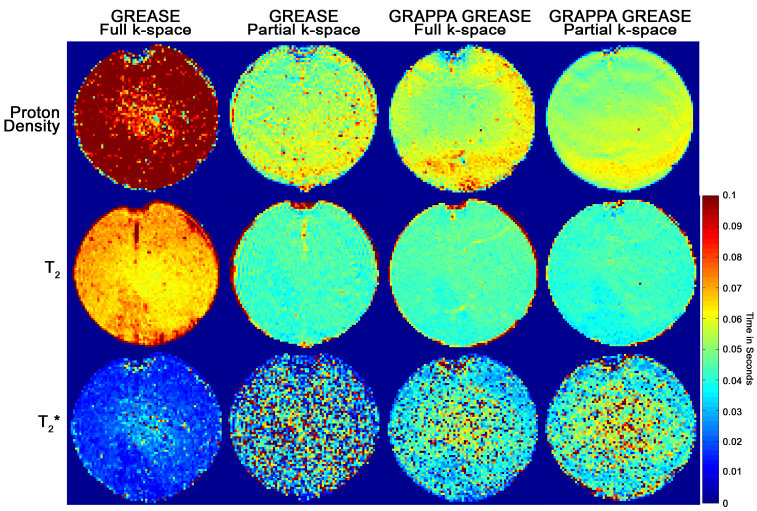
The blood oxygenation level dependent (BOLD) fMRI signal relies upon bulk magnetic susceptibility changes for contrast, physically altering spin dephasing in the imaging voxel and, thus, image intensity [4]. Therefore, BOLD contrast is usually considered in terms of T2*. However, T2* is well known to be comprised of a component that can be refocused with a spin echo, T2', and a component which cannot be refocused, T2, such that $1/T2^*=1/T2+1/T2'$ [5]. The former component relates to spin dephasing while the latter component relates to spin-spin relaxation effects. Thus, T2' is most closely related to the source of the BOLD signal, while T2 is a property that is dependent upon the voxel volume composition. In BOLD studies, it can be useful to separate T2' from T2 effects because T2' temporal contrast is likely to be the signal of interest, while T2 temporal contrast is likely to be a nuisance contrast associated with varying voxel partial volume effects from subject motion. Joint consideration of T2' and T2 can allow researchers to better identify the signal of interest and spurious false positives.

Two techniques were utilized to decrease acquisition time of the GREASE sequence: the first was partial k-space and the second was GRAPPA. Partial k-space acquisitions reduce the duration of the readout portion of the pulse sequence, thereby reducing T2* decay over the readout, more equally weighting k-space lines, and narrowing the point spread function. Furthermore, the method allows a shorter echo time, increasing signal intensity at the center of k-space, and decreasing susceptibility dropout effects in high resolution images [2]. This imaging technique achieves these improvements by acquiring half of the k-space with a few over scan lines and uses the Hermitian conjugate formation to fill in the rest of k-space. The second technique was GRAPPA [3]. The GRAPPA algorithm skips the acquisition of a subset of lines in k-space, using autocalibration (ACS) lines to determine the weightings of observed lines in an array of coils to estimate the skipped lines. The third acceleration technique was a combination of the first two to create a hybrid of parallel and half k-space imaging. All three of these techniques reduce the length of the acquisition, allowing the collection of high resolution images without sacrificing signal intensity, or image quality.

Methods:

Scans were acquired for each one of the four methods using an 8 channel head receiver on a 3.0T General Electric Signa LX scanner, imaging an fBIRN agar phantom. The similarities in the scanning parameters are a TR 2 s, second echo effective gradient echo time (ETE2) TE+20 ms, third echo effective gradient echo time (ETE3) TE+10 ms, flip angle 90 degrees, acquisition matrix 96x96, field of view 24 cm, slice thickness 5 mm, 20 reps. The standard GREASE technique had 48 over scan lines; partial k-space GREASE had 8 over scan lines; GRAPPA GREASE had 48 over scan lines and 4 ACS lines; partial k-space GRAPPA GREASE had 8 over scan lines and 4 ACS. The values for the three echo times and the spin echo are displayed in the table for each sequence. Proton Density, T2, and T2* maps were computed by simultaneously solving the signal equation for the three unknown variables.

Time (ms)	GREASE	Part. GREASE	GRAPPA GREASE	Part. GRAPPA GREASE
TE	51	12	30	9.7
ETE2	71	32	50	29.7
ETE3	61	22	40	19.7
SE	243.76	165.76	158.816	118.216



Results:

The results that are shown in the figure are compared to the gold standard of the spin echo sequence for T2 calculation and gradient echo sequence for T2* calculations on the fBIRN agar phantom, which were determined to be 45 and 40 ms. The GREASE full k-space method results in column one of the figure and shows large errors in the estimations of both T2 and T2*, due to the fact that the third image in this sequence had very little signal. The partial k-space GREASE has a very accurate estimation of T2, and even though the T2* estimation is much better than full k-space it is still rather inaccurate. The second new sequence GRAPPA GREASE had an even more improved estimation of T2 and T2*. Finally the half k-space GRAPPA GREASE had comparable results to GRAPPA GREASE estimation of T2 and T2*.

Discussion:

This experiment establishes that when performing the GREASE sequence for estimation of T2 and T2* the use of sequences to accelerate image acquisition is critical in T2 and T2* calculations. This fact is especially true when increasing resolution from 64x64 to 96x96. With the Partial k-space GRAPPA GREASE in place, the reduction in readout time not only allows for greater accuracy of images, but the ability to acquire more slices in the brain in a given TR. Further work with this sequence could include b-field mapping and correction, which would allow for an even more accurate estimation of the T2*, perhaps allowing mapping of activation from pure T2' changes.

References: [1] Bandettini et al. ISMRM Abstract (1997). [2] Jesmanowicz et al. MRM 40:754-762 (1998). [3] Griswold et al. MRM 47:1202-1210 (2002). [4] Ogawa et al. Nat. Acad. Of Sci. U.S.A. 87:9868-72 (1990). [5] Haacke et al. "MRI Physical Principles and Sequence Design" (1999).