Improvement in Diffusion MRI at 3T and Beyond with the Twice-Refocused Adiabatic Spin Echo (TRASE) Sequence

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Introduction

Diffusion MRI is a popular imaging technique with compelling applications such as the characterization of acute ischemia and fiber architecture. The inherent SNR gains afforded by high field MR scanners (≥ 3 Tesla) offer the promise of improved resolution, but the problems of eddy currents, B_1 inhomogeneity, and RF power deposition are well understood to increase with field strength accordingly.

Reese, et al. have recently shown that eddy-current-induced image distortions can be effectively reduced by using a twice-refocused spin echo (TRSE) sequence (1) in place of the conventional spin echo of Stejskal and Tanner (2). For further improvement at high field, the pair of refocusing RF pulses in the TRSE sequence can be replaced with adiabatic full-passage RF pulses, which offer better B_1 homogeneity and potentially sharper slice selection profiles (3). The cost is increased SAR. This twice-refocused adiabatic spin echo (TRASE) sequence is demonstrated at 3 Tesla.

Methods

The preparation period of a generalized TRSE/TRASE sequence is shown in Figure 1. In both the TRSE and TRASE sequence variants, a slice-selective two-lobe sinc pulse was used for excitation. In the TRSE case, two slice-selective one-lobe sinc pulses were used for refocusing. In the TRASE case, two slice-selective adiabatic full-passage (sech/tanh, R = 10) pulses were used for refocusing.

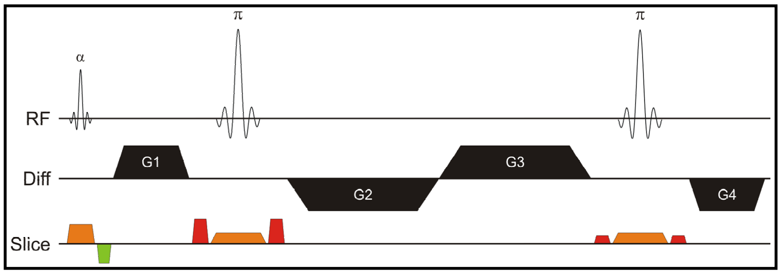

Figure 1. TRSE/TRASE pulse sequence diagram.

Multidirectional diffusion-weighted echo planar images were acquired of a homogeneous phantom using a 3 Tesla Siemens Magnetom Trio whole-body clinical scanner equipped with a standard CP (birdcage) head coil. The measurement parameters used for the TRSE and TRASE sequences were identical in all cases. The image resolution was 2 × 2 × 2 mm (128 × 128 matrix, 256 × 256 mm FOV, 2 mm slice thickness). A total of 64 interleaved slices were acquired over a T_R of 10000 ms with T_E = 88 ms, b = 1000 s/mm^2, and a partial-Fourier factor of 5/8.

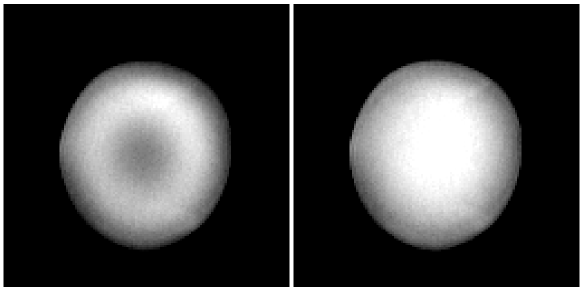

Figure 2. TRSE (left) vs. TRASE (right) phantom images.

Results

Sample TRSE (left) and TRASE (right) images (b = 0 s/mm^2) are shown in Figure 2 for a single slice. The window level is the same for both images. A trace of the center line of each image is also shown in Figure 3.

The TRASE image exhibits improvement in SNR throughout the FOV. At the center of the FOV, the TRASE image has a maximum improvement in SNR of 68%. Average SAR for the TRASE acquisition was 2.9 W/kg vs. 0.8 W/kg for the TRSE acquisition, both of which were well below the FDA limit of 4.0 W/kg and the manufacturer's normal operating mode limit of 3.2 W/kg.

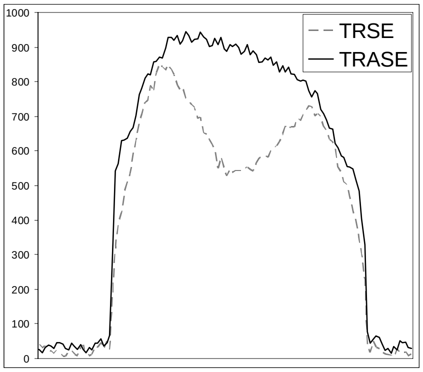

Figure 3. TRSE vs. TRASE intensity profiles.

Discussion

These data suggest that the TRASE sequence can offer significant improvements in diffusion MRI at 3T with a "homogeneous" transmit/receive volume head coil. The increase in SAR is substantial, but with the long T_R typical of diffusion protocols, it is well within established safe limits. The demonstrated improvement in SNR and image homogeneity is gained in addition to the improvements already realized by the TRSE sequence.

At field strengths higher than 3T, the TRASE sequence may prove even more useful. In particular, combined with parallel imaging techniques affording SAR reduction, the TRASE sequence is uniquely suited to overcome the inherent B_1 inhomogeneity of the new generation of surface coil transmit arrays under development at 7T and above.

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References

1. Reese TG, Heid O, Weisskoff RM, Wedeen VJ. Magn Reson Med 2003;49:177-182.
2. Stejskal EO, Tanner JE. J Chem Phys 1965;41:288-292.
3. Garwood M, DelaBarre L. J Magn Reson 2001;153:155-177.