High-Resolution T2*-Weighted Imaging Using Asymmetric Spin Echoes

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Introduction

In fMRI applications, it is needed to acquire T_2^*-weighted single-shot images with high resolution. This is usually achieved by using a gradient echo EPI sequence with a long acquisition window to cover the desired k-space area or multi-shot acquisition. Unfortunately, the long acquisition window is not desirable because it leads to spatial distortion and blurring due to T_2^* decay (e.g., geometric distortion and susceptibility signal loss, etc.) while the multi-shot approach reduces the temporal resolution. In this work, we develop a new acquisition strategy based on asymmetric spin echo that allows the minimization of such distortions. The strategy divides the k-space coverage into the acquisition of an FID and two or more asymmetric spin echo readouts that maintain the T_2^*-weighting of the resultant image. The new sequence is described and the results of its implementation are presented.

Methods

In single-shot imaging, high spatial resolution calls for the use of a long acquisition window leading to severe distortion and blurring. Such artifacts are not as severe with the acquisition of multiple spin echoes due to refocusing. Unfortunately, the spin echo signal is not appropriate for applications that require T_2^* contrast such as BOLD imaging. Here, we combine gradient and asymmetric spin echoes to take advantage of the spin echo refocusing while maintaining the required contrast. As shown in the sequence of Fig. 1 and its k-space coverage in Fig. 2, this is done by filling the k-space coverage with an FID and several asymmetric spin echoes. To further shorten the acquisition window, a partial Fourier coverage is used. The center of the k-space is acquired near the end of the FID at the desired TE and the initial part of the FID covers the required extra lines for the desired partial Fourier reconstruction. After the acquisition of the FID, a 180° RF pulse is applied and then an asymmetric echo is collected before the formation of the spin echo. A second asymmetric echo can also be acquired following the spin echo. The data from the three segments are then concatenated to cover the partial Fourier k-space illustrated in Fig. 2. Notice that this acquisition strategy results in mismatch between signals in different segments due to the imperfection of the 180° RF pulses as well as the time delay in between. In order to avoid artifacts arising from such mismatch, the echo acquisitions are designed to include a few lines of overlap in between segments. These few lines are used to ensure a smooth transition between consecutive segments. The final image is derived using iterative partial Fourier reconstruction [1].

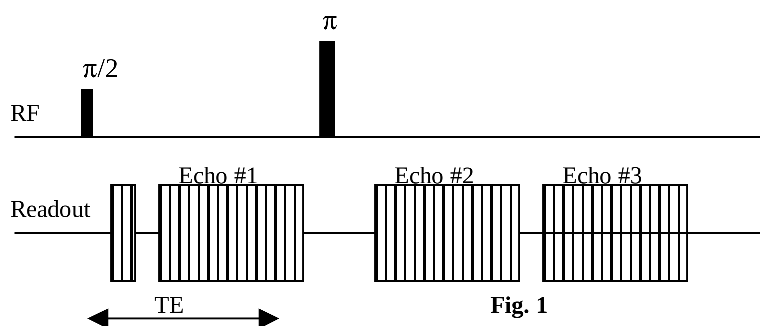

Fig. 1

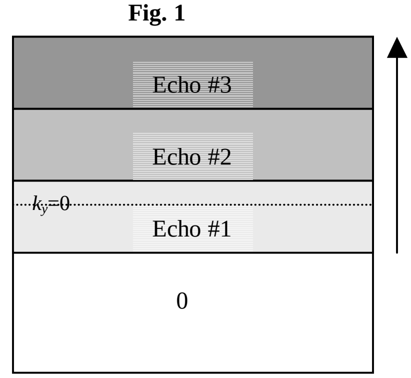

Fig. 2

Results and Discussion

The new sequence was implemented on a Siemens Magnetom Trio 3T MR system with Sonata gradiant system. The acquisition parameters were as follows: spin echo sequence with center at 62 ms, final matrix size: 128×128, EPI factor for asymmetric spin echo segments: 32, FOV: 24cm×24cm, TR/TE: 4000/20 ms, internal phase correction scan of 3 lines, partial Fourier factor: 5/8, and overlap between segments: 4 lines. The results are shown in Fig. 3 where the k-space and the spatial domain of an axial slice acquired from a normal human volunteer are presented. As can be observed, the k-space appears continuous with no apparent mismatch between segments.

Conclusions

A new high resolution EPI sequence based on asymmetric spin echo is developed. The new sequences was described and its implementation results were presented. The new sequence offers reduced image artifacts within virtually the same acquisition time as single-shot gradient echo EPI sequences.

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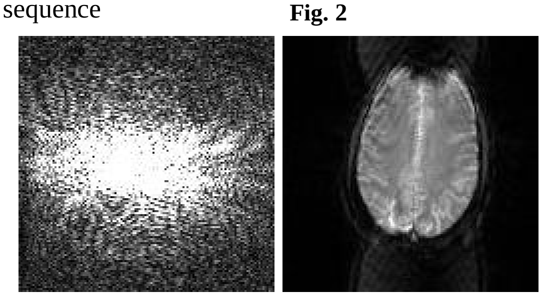
Fig. 3



References
[1] Haacke EM, et al., J Magn Reson 1991; 92:126-145.