High Resolution T2-weighted Imaging with Whole Brain Coverage at 7 Tesla using Multiband Slice Accelerated Spin Echo

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Introduction: The potential of high SNR and enhanced contrast mechanisms at ultra-high field make 7T MRI a promising tool in the diagnoses of neurological diseases. T2-weighted imaging using conventional turbo spin echo (TSE) sequences is a routine clinical sequence at lower field strengths. However, the specific absorption rate (SAR) is one of the primary reasons that prevent the use of conventional TSE methods for T2-weighted imaging at 7T. The SAR can be reduced by reducing the number of slices, prolonging TR, reducing flip angles, and/or compromising RF pulse shapes [1]. Recently, methods such as T2-weighted hyperTSE [2] and 3D variable-flip-angle TSE (SPACE) [3] have been proposed for SAR reduction at 7T. By greatly reducing the refocusing flip angles however, the T2 contrast is compromised. Moreover, the volume coverage of hyperTSE is still limited by SAR, while the long echo train length of SPACE imposes potential blurring through k-space filtering. A spin-echo (SE) sequence may overcome these above issues, but its acquisition speed is too slow for practical clinical imaging. Recent development of multiband slice acceleration technique that simultaneously excites, acquires, and unaliases multiple slices [4-6], can greatly reduces volume acquisition time (TR), and may be extended to spin echo imaging. In this study, we demonstrated the feasibility of multiband slice accelerated SE with SAR optimized pulses for whole brain high resolution T2-weighted imaging.

Methods: Experiments were performed on healthy volunteers using a 7.0T Siemens MRI scanner (Magnetom 7T; Siemens Healthcare, Erlangen, Germany) with a 32-channel transmit-receive head coil (Nova Medical, Wilmington, MA). Multiband RF pulses were generated for simultaneous multi-slice excitation and echo refocusing. The RF pulse duration was 6.14 ms for excitation and 9.21 ms for refocusing. The VERSE technique was applied to the multiband RF pulses to further reduce peak power and SAR. Imaging parameters included: TR/TE = 2360/55 ms, slice acceleration factor = 2, CAIPIRINHA FOV shift factor = 2 [5], excitation/refocusing flip angle = 90º/180 º, slice thickness = 2 mm, 90 Hz/pixel bandwidth, 235×168 mm^2 FOV, 384×276 matrix size, partial fourier factor 6/8, 72 total imaging slices, zero slice spacing. The achieved voxel size was 0.61x0.61x2.0 mm^3. In order to compare the effect on multiband slice acceleration, single-band unaccelerated reference T2-weighted SE images were acquired with 36 slices, 100% slice spacing, and other imaging parameters kept identical to the accelerated scan. The acquisition time was 8:08 minutes for each SE scan. Gray matter/white matter (GM/WM) contrast-to-noise ratio (CNR) was compared between the two scans. Multi-slice 2D gradient recalled echo (GRE) sequence with the same coverage as the multiband slice accelerated SE was used as a calibration scan. Different imaging parameters for the calibration scan included: TR/TE = 359/2.82 ms, flip angle = 25º, 710 Hz/pixel bandwidth, 128×92 matrix size,.

Fig 1. Three orthogonal views of the slice accelerated SE T2-weighted images

Results: The multiband slice accelerated SE sequence successfully executed at 7T, reaching 83% of SAR safety limit on a 79 kg subject. Figure 1 shows the 3 orthogonal views of the slice accelerated SE T2-weighted images. There is no visible artifact and residual aliasing on the axial image. Figure 2 shows the unaccelerated SE T2-weighted images from the same axial slice. The image contrast is similar between the reference and the accelerated scan (Fig. 1), both with strong T2 weighting. Two additional slices with lower and higher positions from the reference and slice accelerated scans are compared in Figure 3. Again the image contrast is very similar between the two scans. The measured GM/WM CNR from the multiband slice accelerated SE is 41.9, as compared to 43.2 measured from the unaccelerated SE reference data.

Discussion and Conclusion: Our study demonstrates the feasibility of using slice accelerated SE sequence for acquiring high resolution T2-weighted images with whole brain coverage (72 slices, 2mm thickness). The slice acceleration and SAR reduction are the keys to enable increased coverage of the T2-weighted image acquisition within a reasonable time (8 minutes). Since TE > 30 ms is generally used for generating T2 contrast and the SE sequence has only one refocusing RF pulse, the RF durations can be lengthened without significant impact on the image quality. This simple SAR reduction approach may also be beneficial for SE T2-weighted imaging at field strengths even above 7T. In addition, a low readout bandwidth may be utilized to fill the waiting time between the refocusing RF pulse and the TE, which greatly improves SNR. Even though this study has not optimized the TE for T2 contrast, the GM/WM CNR measured here is comparable to other studies using TSE with 180º refocusing RF pulses [2]. Further development and combination of in-plane parallel imaging with slice acceleration potentially may reduce the scan time of T2-weighted SE to approximately 4 minutes.

Fig 2. Reference T2-weighted SE image

References: [1] Madai, PlosOne, 2012 [2] Danishad, ISMRM 2011 [3] Grinstead, ISMRM, 2010 [4] Larkman, JMRI 2001 [5] Breuer MRM 2005 [6] Moeller, MRM 2010

Reference | Slice Accl. Factor 2 | Reference | Slice Accl. Factor 2
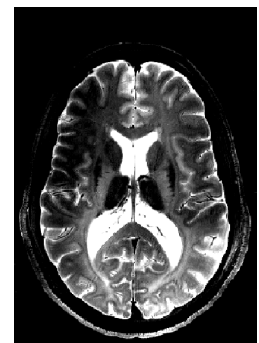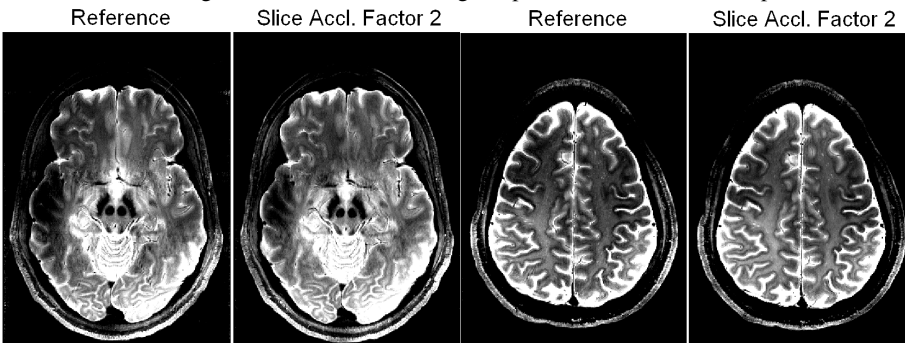
Fig 3. Comparison between reference and slice accelerated SE T2-weighted SE images