Further reduction of SAR for T_2-weighted hyper-TSE imaging at 7 Tesla

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INTRODUCTION

High RF power deposition caused by multiple 180^0 refocusing pulses is a major limitation of turbo spin echo (TSE) sequences in ultra high field MR systems. As an alternative, hyper turbo spin echo sequences (hyper-TSE) can be used to acquire high resolution MR images with reduced SAR, maintaining T_2-contrast and signal-to-noise ratio (SNR) [1]. In this study, the flip angle variation of the hyper-TSE sequence was optimized to further reduce SAR. T_2-contrast and image artifacts of the modified hyper-TSE sequence were compared with standard TSE and hyper-TSE sequences.

MATERIALS AND METHODS

All experiments were performed on a 7T MR scanner (Siemens, Germany) using a 24 channel transmit-receive head coil. A standard TSE sequence with constant refocusing flip angle and a hyper-TSE sequence with freely variable asymmetric FA (TRAPS) were used[2]. The VERSE HF-pulse modification was introduced in both sequences to further reduce SAR. Identical acquisition parameters were used in both sequences TR - 4000ms, TE - 91ms, matrix - 512 x 512, FOV - 200mm, slice thickness - 3mm, echo train length (ETL) - 17, bandwidth - 425 Hz/pixel. In the TSE sequence all the refocusing FA were reduced between 180^0 to 80^0 while in the hyper-TSE sequence the center of k-space FA was varied from 180^0 to 80^0 with corresponding reduction of the surrounding FA (Fig. 1). The contrast to noise ratio (CNR) of grey (GM) and white matter (WM), SAR per slice and possible number of slices were calculated for a human subject.

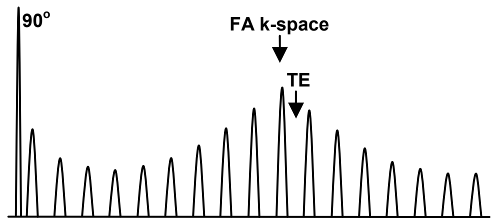

Fig. 1: Refocusing pulses used in HTSE. FA k-space is varied from 180^0 to 80^0. Echo at TE is used to encode the center of the k-space

RESULTS

Figure 2 shows identical slices acquired using the TSE and hyper-TSE sequences. Hyper-TSE images were equivalent or superior to standard TSE in terms of SNR and contrast-to-noise ratios (CNR) for all FA variations (Fig. 3). The hyper-TSE sequence with reduced FA ($140^0/120^0$) is similar to standard TSE with 180° in terms of GM-WM contrast but with a considerable increase in coverage (TSE: 5, hyper-TSE: 21 slices) and reduction in SAR per slice (TSE: 18, hyper-TSE: 5%). Our results indicate that the hyper-TSE sequence with further reduced FA can be used in high-field systems without compromising the T_2-contrast and SNR and with the benefit of increased coverage or reduced SAR.

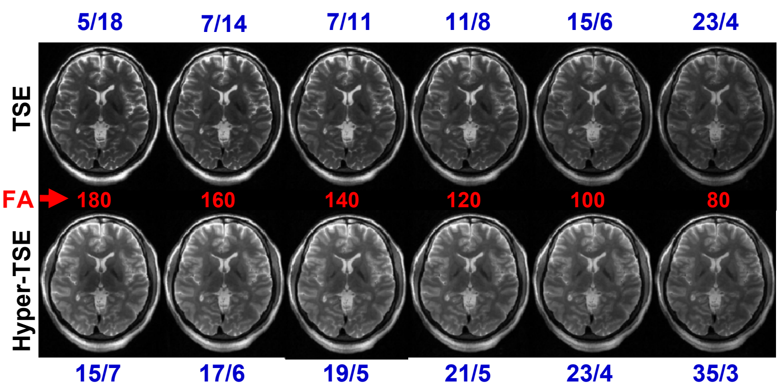

Fig. 2: T_2-weighted TSE (top row) and hyper-TSE (bottom row) images acquired with with different FA (red). The total number of slices/SAR per slice (%) for each sequence is also mentioned (blue)

DISCUSSION

High resolution T_2-weighted spin echo images with thin slices and large volume coverage are desirable at high field MR. However, this is often limited by the high RF power deposition and resulting long TR. Reducing the refocusing FA will reduce the RF power deposition in TSE sequences at the expense of signal intensity and contrast. One of the alternatives is to use the hyper-TSE sequence, which offers large coverage and lower SAR. Until now, the hyper-TSE sequences use a 180^0 FA to encode the centre of k-space to achieve maximum signal intensity with lower flip angles for the remaining k-space lines to reduce the SAR. In this study, we have modified the standard hyper-TSE sequence and acquired images with reduced centre of k-space FA. The results demonstrate that lower SAR and larger coverage, compared to the standard hyper-TSE /TSE 180^0 sequences are possible. With hyper-TSE the signal intensity is maintained by combining the stimulated echoes produced due to FA below 180^0 and the contribution of stimulated echoes increases with further reduction in refocusing FA. Since the T_1/T_2 ratio increases significantly at higher magnetic field strength, this advantage of lower refocusing FA is pronounced, leading to the situation that lower FA result in higher SNR and CNR. The TRAPS ramp-up and ramp-down of the FA required for the hyper-TSE sequence is only advantageous for higher TE and ETL. Moreover, stimulated echoes introduce T_1-weighting, especially with lower FA, which could alter the T_2-contrast, particularly in pathological situations. Further studies are required in this direction. One of the interesting features is the complete absence of artifacts in hyper-TSE images acquired with low FA of 80^0.

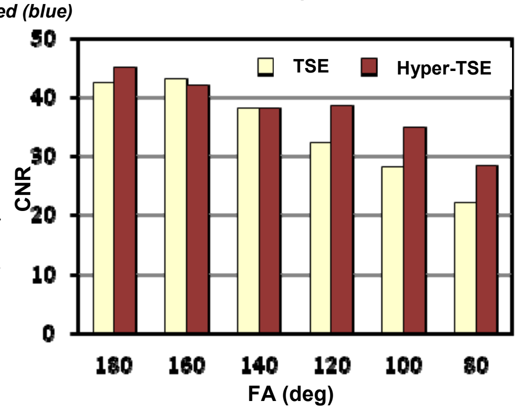

Fig. 3: GM-WM contrast ratio plotted against FA used in TSE and hyper-TSE sequences.

CONCLUSIONS

The Hyper-TSE sequence with further reduced flip angles can be used in very high field imaging with high T_2-contrast and SNR compared to standard hyper-TSE /TSE-180^0 sequences and with higher brain coverage within the given SAR limits.

REFERENCES

1) Weigel et al. MRM 55: 826-835 (2006) 2) Hennig et al. MRM 49:527–535 (2003)