Optimization of HyperTSE at 7T for Efficient T2-Weighted Imaging

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INTRODUCTION

The high SNR achievable at 7T can be utilized to increase the spatial resolution of morphologic T2-weighted images. However, the very high RF-power requirements of multi-spin-echo methods (TSE) can dramatically limit their efficiency. HyperTSE [1] has been proposed in order to reduce the specific absorption rate (SAR) in TSE without compromising image quality. At 3T this is now routinely used to allow highly efficient T2-imaging. At 7T, however, such measurements are again limited by SAR restrictions.

The purpose of this study was to further optimize the RF-pulses and the flip angle (FA) variation in order to allow for T2-weighted imaging at 7T with high resolution and high volume coverage without increased scan times imposed by SAR limitations.

MATERIALS AND METHODS

All experiments were performed on a 7T system (Siemens, Erlangen, Germany) using an 8 channel head array coil for transmission and reception. TSE sequences with constant as well as with varying refocusing FA (hyperTSE) were used. Common parameters for all sequences were: TE 72ms, TR 4000ms, matrix 512*512, FOV 220mm, slice thickness 2mm, gap 1mm, echo train length 9, bandwidth 130Hz/px, pulse length 7.68ms. As a reference, all refocusing pulses were set to 180°. In order to reduce SAR, different pulse shapes (sinc or gaussian) and flip angle variations were compared: a) constant but reduced FA; b) first refocusing FA set to 90°+FA/2 [2]; c) standard hyperTSE with Gaussian FA ramp and 180° for k-space center; d) hyperTSE with sinusoidal FA ramp and reduced k-space center FA. Images were evaluated with regard to the SAR, signal in gray matter, white matter and CSF, noise, apparent resolution, and artifacts. Measurements were performed in human subjects and phantoms.

RESULTS

Fig. 1 shows that the image quality and resolution compared to the reference acquisition is unaltered as long as the k-space center refocusing FA is not too low (~110°). For the FA variation schemes used in this study, this is independent of the type of variation. The choice of the pulse profile resulted mainly in a reduction of CSF signal by about 15%. The images acquired with a Gaussian refocusing pulse show significantly reduced fat signal. The SNR values are displayed in the graph. The yellow boxes show the SAR per slice and the corresponding maximum number of slices.

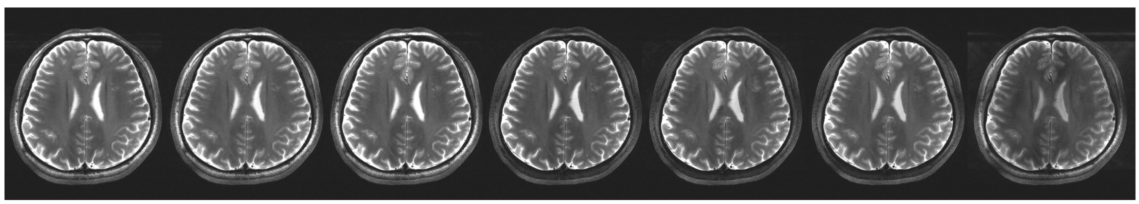
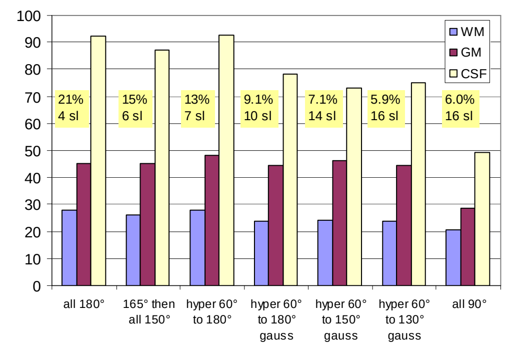


Fig. 1: The center slice out of multi-slice data ordered identical to the results in the graph. The tissue signal and contrast remains very high for all but the right image with 90° refocusing FA (identical image scaling).



DISCUSSION

With the reduction of SAR by means of more 'radical' flip angle variations, high quality T2-weighted images can be acquired at 7T with increased number of slices and thus high volume coverage. The images do not show any apparent reduction in resolution of fine structures and only some reduction in CSF signal. GM and WM signal is maintained due to T1 contributions to the decay via stimulated echo pathways. Interestingly, the GM/WM contrast is also maintained for the hyperTSE measurements with lower refocusing flip angles despite the fact that the nominal TE was kept constant [3].

Compared to lower field a prolongation of RF-pulses was still necessary in order to allow execution of the reference method (180°) with at least 3 slices. This leads to a reduced efficiency of the method since the RF-pulse time could either be used for longer readout (reduced bandwidth) or to encode more echoes within TE. This is in part caused by a conservative setting of the SAR limits for the coil used. For safety reasons these have been reduced by a factor of 2 compared to the theoretically achievable value as predicted by local SAR from EM-simulations. If the simulation values were used, the hyperTSE method with FA varying from 60° to 130° allows for the acquisition of 32 slices with a TR of 4s, thus limiting the efficiency not by SAR but by the timing of the sequence.

It has to be considered that the FA is not well defined at 7T due to B1 inhomogeneity and significant variations of more than 30% exist within the slice displayed. Therefore it is very promising that the images show very little inhomogeneity despite the fact that they are not corrected for B1-inhomogeneities.

Due to the broader frequency range of the Gaussian refocusing pulse, the fat signal may not be as efficiently refocused. Therefore these images are more similar to conventional spin echo data without the known TSE fat enhancement. A detailed analysis of this behavior still needs to be performed. Further methods for SAR reduction such as VERSE or SENSE can be combined with the FA variation. However, for shorter echo train lengths achievable with SENSE, the flip angle variation is more limited and therefore less efficient. In conclusion, with the modifications introduced, high-resolution T2 weighted imaging at 7T is possible with large volume coverage and short scan times.

REFERENCES

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