Low SAR Inversion Recovery Weighted TSE Sequences using TRAPS: Parameter Optimization and Examples

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Purpose

Turbo spin echo sequences (TSE) are the workhorse in diagnostic MRI due to their clear T1 and/or T2 weighted contrast behavior and insensitivity to susceptibility effects combined with short scan times. Recently, novel acquisition techniques for TSE sequences such as hyperechoes [1] and TRAPS [2] have been proposed to reduce rf power deposition while maintaining SNR and contrast (hyperTSE sequences). Besides T1 and T2 weighting IR weighted TSE sequences are of great importance in diagnostic and clinical routine MRI. This contribution shows that hyperTSE sequences can also successfully produce high quality IR weighted images, but with a significantly reduced SAR compared to TSE180°. Both, results of theoretical calculations and first experiments are presented for three common types of IR weighted TSE sequences (T2 weighted STIR [3,4], FLAIR [5,6], GM/WM-IR).

Subjects and Methods

Signal behavior of the TSE sequences was simulated using MATLAB (Mathworks Inc.) and C++. For this the extended phase graph concept [7] was employed. Exemplary calculations were done for tissue with T1=1000ms and T2=100ms. MRI sequence specific parameters were used in accordance with the investigated types of sequences. All imaging experiments were performed on a 3T whole-body scanner (Siemens Trio, Erlangen, Germany). A common TSE sequence (in-plane resolution=$(0.6\text{mm})^2$, ETL=17, ESP=12ms, slth=3.5mm) was employed, in which the TRAPS-mechanism was implemented according to [2]. Contrast specific parameters were for the (A) FLAIR type TI/TE/TR=2500/116/10000ms, (B) GM/WM-IR type TI/TE/TR=860/12/5000ms, and (C) T2 weighted STIR type TI/TE/TR=160/68/3000ms if not specified otherwise.

Results

Generally, it can be deduced from a first consideration that TI does not need to be changed between conventional and hyperTSE sequences, since T1 relaxation after an inversion pulse is independent from the following method of k-space sampling. Focusing first on (A) the FLAIR type, **Figure 1** shows a plot for the signal behavior for tissue with T1=1000ms and T2=100ms. After T1 relaxation during the intervall TI the present z-magnetization is transformed into transverse magnetization for k-space sampling. Compared to a conventional FLAIR (blue dashed curve) that suffers pure T2 decay the relaxation of the corresponding hyperFLAIR is prolonged due to stimulated echo contributions (red curve). Thus, there is more signal left at echo time TE which cause hyperFLAIR sequences to possess a higher intrinsic SNR than their conventional counterparts in general. Since the prolongation of signal relaxation depends on the refocusing flip angles and the tissue specific T1, a hyperFLAIR sequence exhibits a different contrast at same TE. Therefore a correction of TE is necessary to achieve an equivalent tissue contrast as the TSE180° again. For the employed hyperFLAIR the corrected TE can be estimated to TE=142ms (i.e. TEeff=116ms). **Figure 2** shows examplary FLAIR images that confirm these theoretical considerations. In **(a)** a conventional FLAIR image is presented, in **(b)** the corresponding hyperFLAIR image. Correcting TE to the same effective TE leads to a FLAIR image with same contrast again **(c)**, but the SAR deposited is 61% less with the hyperFLAIR. The same considerations were also performed for the (B) GM/WM-IR and (C) STIR sequence type. The GM/WM-IR provides maximum contrast between WM and GM. Since TE=min. no corrections of TE for a prolonged T2 decay is necessary. A comparison of both resulting images displays **Figure 3**. For the STIR type corrections of TE depend on the actually chosen TE in the scanner protocol. So it can be considered either as case (A) or (B). **Figure 4** presents an example with TEeff=68ms (i.e. TE_{conv}=68ms, TE_{hyper}=79ms). Both, hyperSTIR and hyperTSE GM/WM-IR images had a SAR_{saving} of more than 60%.

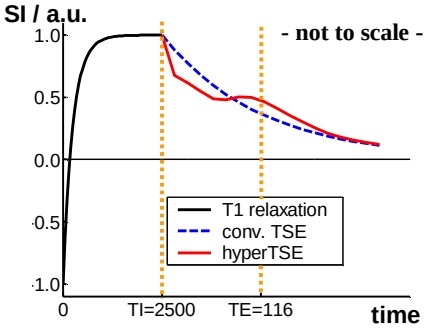

Figure 1: Comparison of different signal behavior for the used conventional FLAIR (blue dashed curve) and the hyperFLAIR (red curve) after T1 relaxation (black c.).

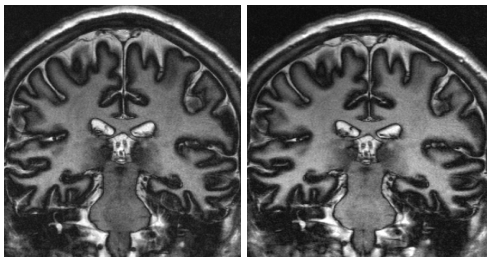

Figure 3: Comparison of GM/WM-IR images: conv. TSE (left), and hyperTSE (right).

Discussion and Conclusion

It was demonstrated that hyperTSE sequences are capable of acquiring high quality IR weighted images (FLAIR, GM/WM-IR, and STIR) without any degradation in image quality. SAR deposition can be reduced by as much as 65%. For all T2 weighted IR weighted TSE images such as FLAIR a correction of TE is necessary to achieve the same contrast as with a conventional TSE180°. This correction can be estimated from the chosen hyperTSE sequence and can thus be implemented into the sequence. This was already done in our lab. The gained reserve in SAR was used to achieve longer echo train lengths (leading to shorter acquisition times) and a larger amount of slices.

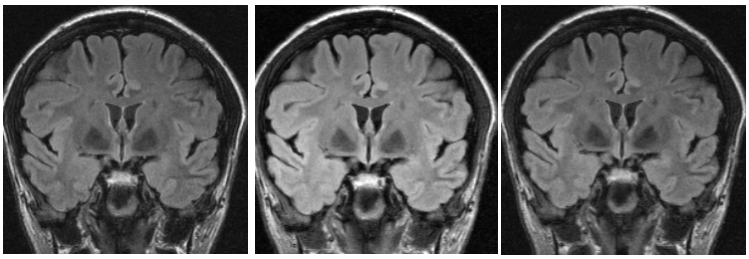

Figure 2: Comparison of FLAIR images: conventional FLAIR with TE=116ms (left), hyperFLAIR with TE=116ms (center), hyperFLAIR with corrected TE=142ms (i.e. TEeff=116ms, right)

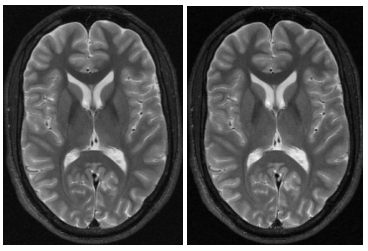

Figure 4: Comparison of T2 weighted STIR images: conv. STIR (left) and hyperSTIR (right).

References:

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