Predicting the Contrast of Generic Lower Flip Angle TSE Sequences with the Extended Phase Graph and its application

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Purpose

The application of turbo spin echo sequences (TSE) is frequently limited by SAR restrictions. Thus, a reduction of the (constant) flip angle and more sophisticated rf pulse schemes such as TRAPS [1] (hyperTSE) are used to solve this problem. However, as with all lower flip angle TSE sequences contrast changes. To address this issue for clinical routine MRI it would be very helpful to theoretically assess the contrast of any generic TSE. The purpose of this abstract is to demonstrate that the Extended Phase Graph (EPG) concept [2] is a valid and helpful tool to calculate the signal intensity of any tissue in a TSE sequence with arbitrary flip angles. Thus, its intrinsic contrast can be predicted and specific contrast corrections can be directly implemented into the TSE sequence.

Subjects and Methods

All experiments were performed on a 1.5T (n=10) and 3T (n=13) whole-body imaging system (Siemens Sonata and Trio). A common TSE sequence (matrix=256x208, slth=5mm) was employed. Besides five low constant flip angles (180°, 150°, 120°, 90°, 60°) six different schemes of varying flip angles (ranging from 180° down to 90° or 60°) using TRAPS were implemented. A protocol with two different echo times (TE=80ms, TE=134ms) and two different echo train lengths (ETL=15, ETL=25) of the eleven sequences was investigated. Prior to the study T1 and T2 relaxation times were assessed. Experimental signal intensities $I_{measured}$(sequence,tissue) were evaluated in global ROIs of WM, GM, and CSF for each tissue and sequence. The corresponding theoretical signal predictions were calculated via the EPG concept. Both were compared to test whether

[Eq.1] $\mathbf{I_{measured}(sequence,tissue) = PD_{tissue} * f_{EPG}(\alpha_i, T1_{tissue}, T2_{tissue})}$. PD_{tissue} is a measure for the tissue specific proton density and constant for each volunteer. The quantity was computed for each tissue per acquired dataset as the mean ratio of all evaluated signal intensities and their corresponding predictions (also refer to **Figure 1**).

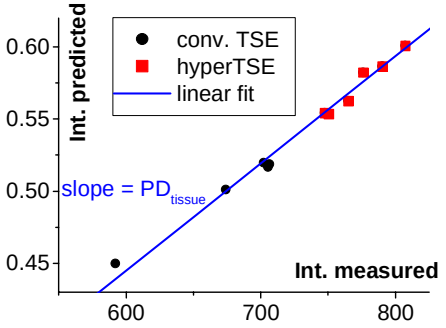

Figure 1: Measured intensites vs. intensity predictions for gray matter of one volunteer. The direct proportional behavior can be observed (R=0.99). The slope corresponds to PD_{tissue}.

T / ms	CSF	GM	WM
T1_1.5T	3916±828	1213±26	679±20
T2_1.5T	1356±626	131±12	100±5
T1_3T	3651±421	1543±50	907±27
T2_3T	1440±478	125±8	94±3

Table 1: Relaxation times at 1.5T and 3T

<ΔI> in % at 3T	CSF	GM	WM
TE=80, ETL=15	0.81%	0.04%	0.99%
TE=80, ETL=25	1.05%	0.03%	1.04%
TE=134, ETL=25	1.15%	0.37%	1.10%
TE=134, ETL=15	1.09%	0.42%	0.91%

Table 2: Relative deviation between signal predictions and measured intensities averaged over all volunteers and sequences at 3T. The values correspond very well for the whole protocol.

Results

Table 1 presents the determined mean relaxation times that were used for the tissue specific signal predictions. As an example, **Figure 1** displays the evaluated signals versus the corresponding signal predictions for gray matter of one volunteer dataset. The direct proportional behavior (R=0.99) can be observed well. This validates the approach to assess one specific (constant) proton density per tissue and per volunteer used for Eq. [1]. **Table 2** presents an overview of the relative deviations between measured signal intensities and its predictions averaged over all volunteers for the whole protocol. All signal deviations at 3T are less than 1.2% for all types of tissue and sequences showing a very good agreement between theory and experiment. Thus, the contrast of any TSE with arbitrary flip angles can be predicted. The results for 1.5T were found to be similar (not shown). The demonstrated validity of the EPG model was used to introduce an automated T2 weighted contrast correction for hyperTSE sequences in clinical routine MRI. **Figure 2** presents an example for this technique. The hyperTSE image of a patient with a pilocytic astrocytoma displays the same T2 weighted contrast as the conventional TSE [3].

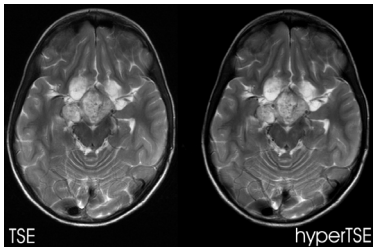

Figure 2: Comparison of a TSE and hyperTSE image at 3T from a patient with a pilocytic astrocytoma (clinical routine MRI). An intrinsic T2 weighted contrast correction with the validated EPG concept was employed. Both display the same contrast and resolution.

Discussion and Conclusion

It could be shown that the Extended Phase Graph concept can accurately predict the signal intensities of any tissue in generic TSE sequences at 1.5T and 3T. Thus, it is feasible to use this technique, for example, to implement specific contrast corrections into a TSE sequence. This is pointed out in **Figure 2** where the T2 weighting of a hyperTSE was automatically adapted to that of a TSE180°. Such methods are important for applying lower flip angle sequences in clinical routine MRI and for further conceptual understanding.

References

[1] Hennig J, Weigel M, Scheffler K. MRM 49: 527-35
[2] Hennig J. Conc Magn Reson 3: 125–43
[3] Hennig J, Weigel M, Scheffler K. MRM 51: 68–80