Systematic Comparison of Quantitative T1 Mapping Methods at 7 T High Field

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INTRODUCTION

Quantitative MRI offers many advantages in diagnosis and also in longitudinal or cross-sectional studies. The measurement of T_1 is of particular interest. However, many T_1 quantification methods rely on accurate knowledge of B_1 which varies significantly over the field of view (FOV) at high magnetic field. TESSA as a new method for rapid and simultaneous mapping of T_1 and B_1 has been presented [1]. It exploits the transition of fully relaxed magnetization into steady state given by TR, T_1, alpha, and B_1. In this study the accuracy and efficiency of the TESSA at 7 T is compared to other established T_1 quantification methods [2].

THEORY

As described in [1] B_1 and T_1 can be obtained from a series of α-pulses separated by TR, which drives the magnetization from full relaxation into equilibrium. The magnetization after the (n+1)th pulse is $M_{n+1} = M_0(1-E_1) + M_n\cos(\alpha)$ and the resulting Signal is $S_{n+1} = M_{n+1}\sin(\alpha)$. In a linear fit of $\Delta n = (S_{n+1} - S_n)/S_0$ over S_n/S_0, the slope B and the intercept A contain $T_1 = -TR/\ln(1-A)$ and the flip angle $\alpha = \arccos((1+B)/(1-A))$. Therefore, this method should be tolerant against B_1 variations and delivers a B_1 map in addition to T_1 map.

METHODS

In order to test TESSA and to compare it to other T_1 imaging methods, TESSA, Inversion Recovery (IR), Saturation Recovery (varying flip angle SRFA and TR SRTR) and IR-Look-Locker (IRLL) were simulated with varying nominal T_1, noise, and flip angle-deviation FA/FA_{nom} (k). Therefore, signals for 1000 noise realizations were generated and T_1 and B_1 were fitted using established signal models. The fitting was done within Matlab. Systematic errors in T_1 and B_1 quantification as well as quantification accuracy were determined. To validate the simulations, measurements were performed on a Siemens 7 T system. T_1 and B_1 maps were determined in carrageen phantoms [3] and in a volunteer using an 8-channel Tx/Rx coil.

RESULTS & DISCUSSION

The Results of the simulations are shown in Fig.1. The systematic errors arising from incorrect flip angles are very small with TESSA and IR (<1%) whereas those for SR and IRLL are much higher. Such systematic errors arise from the ambiguity of the signal with regard to k and T_1 that leads to amplification of the systematic errors even for small noise. Therefore, these three methods are not suitable for obtaining T_1 map without acquisition of a separate B_1 map. Presuming correct flip angles in the fitting procedure for those methods does not lead to improvements in systematic errors. Thus, for high field studies, only the B_1 resistant methods, e.g. IR and TESSA were performed.

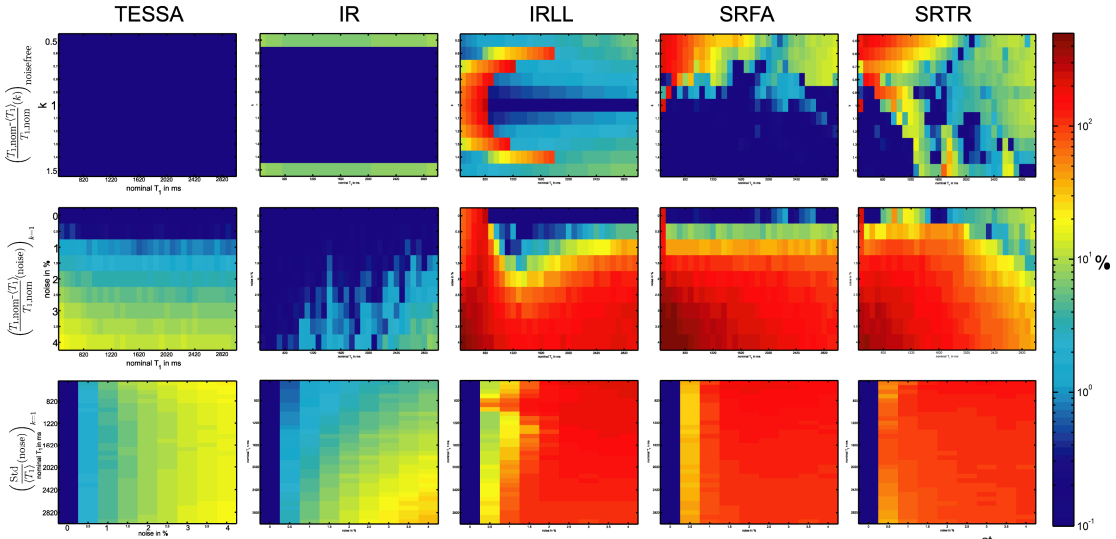

Fig 1: The 1000 iteration leads to the systematic error and the STD of T_1 for the diverse methods. The 1st row show systematic error rising from false flip angles, the 2nd row these from noise. The 3rd row presents the STD over noise.

The phantom and *in vivo* results are presented in Fig.2. The high quality IR phantom T_1 map was acquired from a 1 hour GRE measurement with 1.6x1.6x5 mm³ voxel size and a SNR of 320, while the TESSA T_1 maps are obtained from a 10 s scan with EPI-readout and 1.4x1.4x2 mm³ voxel size with SNR 57 (phantom) and 40 (*in vivo*). To accelerate the *in vivo* measurements, IR were combined with EPI with 1.4x1.4x2 mm³ voxel size and scan time of 450 s (SNR 43). T_1 maps from IR show better results compared to TESSA in phantom due to the 5-fold higher SNR and less distortion from GRE. On the other hand, the *in vivo* T_1 maps from TESSA show a clear definition of GM and WM compared to IR with a 10 s acquisition. The contrast is especially pronounced in the ventricles, where TESSA separates well the local structure. By averaging multiple measurements, the short acquisition time of TESSA could be exploited to increase the SNR and accuracy without a significant sacrifice in total acquisition time compared to IR.

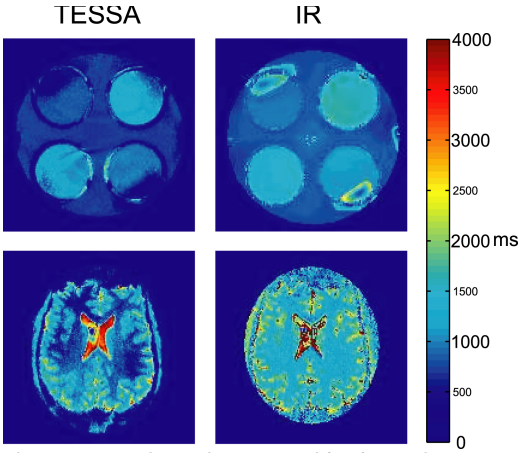

Fig 2: T_1 maps from phantom and *in vivo*. Left: TESSA EPI: FA=50° TR=0.2s Right upper: IR-GRE TR=10s. Bottom right: IR-EPI: TR = 10 s.

CONCLUSION

TESSA is a promising alternative for fast T_1 mapping at high field since it is not sensitive to flip angle deviations and is able to additionally estimate B_1. Other methods need an extra B_1 map for correct T_1 estimation and/or require very long acquisition time. The T_1 fitting algorithm for TESSA is much faster and easy to implement.

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REFERENCES

[1] Zhong *et al*. ISMRM 16, 2008 [2] Crawley *et al*. MRM 7: 23-34, 1988 [3] Trantzschel *et al*. German Chapter ISMRM 10, 2007