# Optimization of T1 Measurement using Mixed Flip Angle and TR

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**INTRODUCTION:** Accurate determination of $T_1$ values in the brain is clinically important for the diagnosis of epilepsy and Parkinson's disease and also for the successful execution of perfusion and dynamic contrast agent studies. Currently, the gold standard method is 2D inversion recovery fast spin echo, which suffers from the long acquisition time and limited coverage. Although a number of alternative methods have been developed for the rapid and accurate quantification of the cerebral $T_1$ map, relatively low signal-to-noise ratio and long acquisition time associated with these newer methods reduce their appeal.[1] In practice, a 3D gradient echo approach with variable multiple flip angles (FA) and repetition times (TR) have been frequently used for $T_1$ quantification. However, inaccurately applied FA and under-optimized signal sampling have limited the $T_1$ quantification accuracy. In this work, we propose a clinically practical $T_1$ measurement method using the widely available 3D gradient echo sequence and the optimized acquisitions with mixed FA and TR for efficiently and accurately calculating $T_1$ maps in the brain.

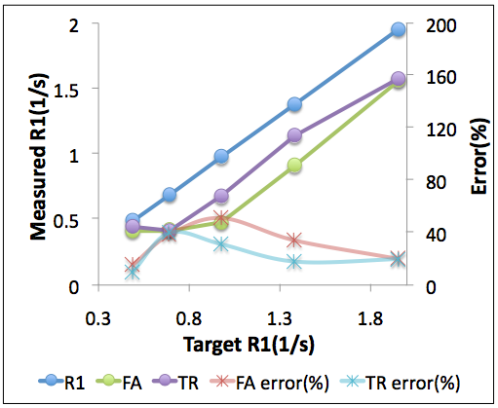


**Fig 1. Underestimation effect and errors of conventional methods**

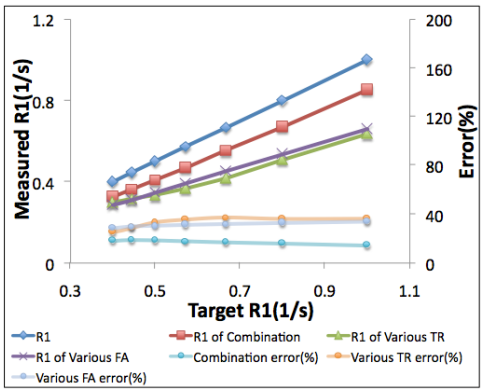


**Fig 2. R1 values and errors**

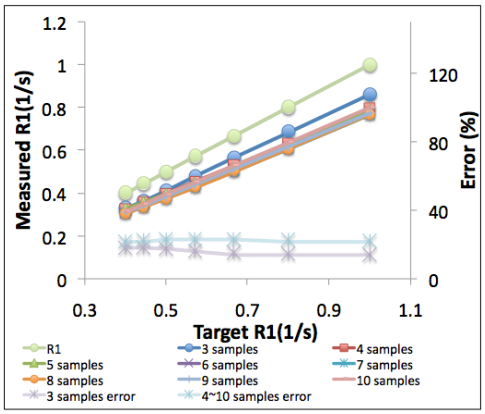


**Fig 3. Influence of sampling number**

**MATERIALS & METHODS:** Signal simulation of the conventional gradient recalled echo (GRE) was performed with the inclusion of white noise and errors in applied flip angles. For optimizing the measurement accuracy, we investigated various measurement strategies and determined the proper number of samples and optimal sets of FA's and TR's. First, conventional R1 measurement method using variable FA's and variable TR's was computed. Variable FA (VFA) method had TR=7ms, FA=[2 5 7 10 15 20]$^{o}$. Variable TR (VTR) method had FA=90$^{o}$, TR=[7 15 20 25 30 35] ms. Unless specified otherwise, all the tested methods had the same number of signal samples for R1 calculation, which was set at 6. Matlab and AFNI were used for signal simulation and R1 fitting, respectively. Finally, we investigated the use of multiple combinations of both variable FA and TR. For MRI data acquisition, a phantom with plastic tubes containing various concentrations of contrast agent (Gd-DTPA) in distilled water was used at 3.0T Siemens scanner. Axial images were acquired.

**RESULTS & DISCUSSION:** Fig. 1 shows representative R1 data sets obtained from the MRI phantom data. The experimentally measured R1 values are significantly underestimated for both VFA and VTR methods when compared to the target R1 values. Possible reasons for such errors are (1) difference between applied flip angles and nominal flip angles used for R1 fitting, (2) variable SNR dependent on the pulse sequence parameters, and (3) poor spoiling. Despite these negative factors, we hypothesized that combining VFA and VTR methods compensates the measurement errors involved with each method and improves the measurement accuracy. In fact, the simulation data show that our new combination method using a set of mixed FA's and TR's produces results closer to the target R1 than when either VTR or VFA method is used alone (Fig. 2). Fig. 3 presents the dependence of performance on the number of sampled signals. The accuracy was optimized when random 3 data points from each VFA and VTR method (total of 6) were chosen. The improved performance using the combination method may be related with the increased data dimension. In this study, a new method to assess the accurate R1 values is suggested and evaluated. The combination method is an attractive alternative to other conventional methods, which may provide more accurate R1 values in total acquisition time under 10 minutes.

**REFERENCE** [1] SCL Deoni et al. Magn Reson Med. 2003;49(3):515-526