Rapid Data acquisition for T1 Mapping, using Multishot EPI and Automated TR Variation at 3T

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INTRODUCTION: Rapid measurement of T_1 is an essential part of quantitative dynamic contrast enhanced MRI (DCE-MRI). The inverse of the measured T_1 is the relaxation rate R_1 which is linearly related to gadolinium concentration over a wide range. Existing fast methods of T_1 measurement (Look-Locker EPI, IR-EPI) [1] provide high temporal resolution, but spatial resolution is limited by susceptibility artifact and accuracy is degraded by RF inhomogeneity. Conventional spin-echo imaging with inversion-recovery (IR) or saturation-recovery (SR) provides high spatial resolution but limited temporal resolution. We present a new method of T_1 measurement which uses saturation recovery and multishot EPI with variable TR and nonlinear fitting of the relaxation curve. Precontrast images allow calculation of equilibrium magnetization M_o, a quantity which depends on proton density, imaging voxel dimension, magnetic field strength, and the temperature, but not upon T_1,[2] and can be included as an additional point for curve fitting.

METHODS: A multishot spin-echo EPI (ms-SEPI) sequence with presaturation pulses and dynamically variable TR was implemented on a Siemens Trio 3T MRI system. T_1 measurement was accomplished by fitting multiple data points obtained with varying TR and constant TE to a relaxation curve. The calculation of T_1 from these data points was performed pixel-by-pixel, using the standard saturation recovery spin-echo equation,[2] $S(\vec{r}:TR,TE) = S(\vec{r}:\infty,TE)\cdot\left(1-e^{-TR/T_1(\vec{r})}\right)\cdot e^{-TE/T_2(\vec{r})}$. Curve fitting was performed with a nonlinear Levenberg-Marquardt algorithm. The relaxivity $\Delta R_1(\mathbf{r})$ was calculated as $\Delta R_1(\vec{r}) = 1/T_1(\vec{r},t) - 1/T_{10}(\vec{r},t)$. The technique was validated by comparison with IR-SE using an agar phantom with TR's of 150, 250, 400, 800, 1400, 2200, 3200, and 5000 ms. *In vivo* studies were then performed in mice with a reduced number of data points at TR's of 250, 500, and 800 ms. Axial images at three TR's with 64 x 32 image size, 1.0 mm inplane resolution, and 8 2mm thick slices were obtained with a total imaging time of 15 sec. Precontrast T_1 mapping data was acquired with 8 different TRs and used to calculate baseline relaxivity $1/T_{10}(\mathbf{r})$ and the equilibrium magnetization $M_o(\mathbf{r})$. An echo train length of 3 was used to limit susceptibility artifact. Slice number was limited by the shortest TR (250 ms) but could be increased with more sophisticated interleaving without increasing total scan time.

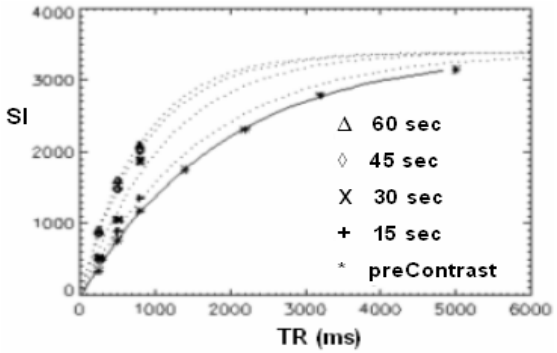

Figure 1: ***Plots of the precontrast and dynamic signal intensity, and their fitted T_1 recovery curves of a single pixel in the periphery of a tumor, indicated by an arrow in Fig. 2, at different time points before and after administration of contrast.***

RESULTS & DISCUSSION: The signal recovery plots and fitted relaxation curves from an *in vivo* mouse experiment are shown in Fig. 1. Shortening of T_1 after administration of contrast is demonstrated. Data for each post-contrast time point were obtained at three values of TR in a total of 15 seconds with sequence parameters described above. The calculated T_1 maps are displayed in Fig. 2 for a representative axial slice through a tumor. Comparison was made with T_1 values obtained by saturation recovery spin-echo imaging, and good agreement was seen. Selection of TR points depends on the range of T_1 for the dynamic data acquisition. Data acquisition with TR of 250, 500, and 800 ms may not provide accurate T_1 estimates for short T_1, e.g., below 250 ms. More sophisticated interleaving strategies may allow acquisition of shorter TR data points without decreasing the number of slices imaged.

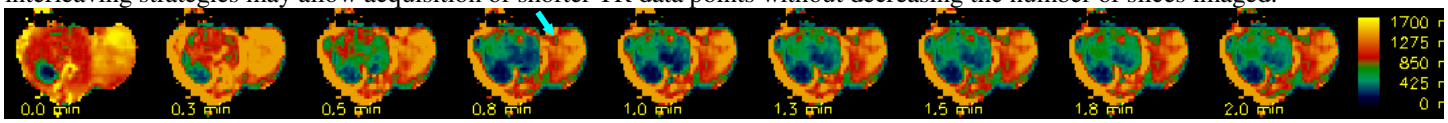

Figure 2: ***. T_1 maps at different time point, including the precontrast T_1 map (the 1st image). T_1 becomes shorter toward the dark colors (blue). T_1 at the peripheral rim of the tumor decreases with time consistent with increasing gadolinium concentration.***

CONCLUSION: A rapid acquisition technique for T_1 mapping was developed using multishot EPI with dynamic TR variation which has decreased sensitivity to B_1 inhomogeneity compared to existing rapid T_1 mapping methods. This sequence was used to acquire quantitative T_1 measurements in mice with DCE-MRI. The resultant T_1 values were comparable to those measured by saturation recovery spin-echo imaging but were obtained much more rapidly. Flexible tradeoff can be made for even shorter imaging times at the expense of increased image distortion from susceptibility.

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