An improved three-dimensional Look-Locker sequence for T1 measurements

Cheukkai Hui[1], and Ponnada Narayana[2]

[1]cheukkai.hui@uth.tmc.edu, Houston, Texas, United States, [2]Radiology, UT Health, Houston, Texas, United States

Objectives

The spin-lattice relaxation time (T_1) is one of the most basic parameters in MR imaging, including quantitative perfusion imaging. The Look-Locker (LL) approach [1] has been widely used for fast T_1 mapping. In this study, we propose a truly centric k-space segmentation encoding scheme for 3D LL acquisition to enhance the data quality. In addition, we propose a multi-step fitting algorithm which utilizes a χ^2 weighted angle maps for improving the accuracy of T_1 measurements.

Methods

Since the central k-space contributes more to signal intensity, a centric encoding scheme in which the central k-space is acquired first is generally used in the LL sequence. Traditionally, such centric encoding scheme is limited to single phase encoding dimension (k_y) [2,3] and is not exactly centric. In our implementation, a truly centric acquisition in both phase encoding directions is adopted as shown in Fig[1].

For T1 estimation, a four parameter (tip angle α, inversion angle γ, equilibrium magnetization M_{eq} and T_1) fit on a coarse resolution image series is performed first to obtain the maps of α and γ. Since the accuracy of angle calculation is important for estimating the T_1 values and could be affected by signal fluctuation, we propose to smooth the angle maps based on their respective χ^2 weighting of the fit. Calculation of the smoothed angle is described in the following equation:

$$\angle = \frac{\sum_i \left(2.0\overline{E} - E_i\right)\angle_i}{\sum_i \left(2.0\overline{E} - E_i\right)} \text{ with } E_i = \overline{\sigma}_i \sqrt{\chi_i^2}$$

χ_i^2 is the weighting of the fit in region i, $\overline{\sigma}_i$ is the average standard deviation of the corresponding signal. $\overline{E}$ is the mean of all E_i within the averaging kernel. The summation includes all non-zero angles within the kernel that have E_i below

Figure 1 Example of 3D LL segmentation scheme (fully sampled k_x not shown). Data with the same color are acquired after the same inversion pulse, and the numbers represent the order in which the data is sampled. Time point at which "1" is taken is assigned as the time point of the reconstructed signal. a) Traditional scheme is confined to 1D segmentation b) proposed scheme expands centric encoding to both phase-encoding direction.

$2.0\overline{E}$. The factor 2.0 is chosen so that angles obtained from bad fits (approximately 5% of data with very high χ^2) are eliminated while angles that show good fit are weighted appropriately. The angle maps are then smoothed with a median filter. A two parameter (M_{eq} and T_1) fit with the fixed angle maps is used to create the final T_1 map.

A series of LL acquisitions with different delay times and different tip angles were performed on a gel phantom and the corresponding T_1 maps were computed using the proposed method. In addition, T_1 map was acquired with a spin echo inversion recovery acquisition, considered to be the gold standard, for comparison. T1 map of rat brain was also acquired from the proposed LL sequence.

Results

The calculated T_1 values of the gel phantom show excellent agreement with all LL measurements and also agree with the T_1 value derived from the inversion recovery sequence. The maximum difference in the average T_1 values is less than 4% for all the LL acquisitions; and less than 7% compared to the inversion recovery sequence. Fig 2 shows an example in which the proposed multi-step fitting can be superior to using the nominal angle or an average angle map [3]. Fig 3 shows an example of the T1 map of a rat brain and selective fitted curves for different tissues using the proposed LL procedure.

Discussions

An improved k-space segmentation scheme is implemented on a 3D LL sequence to improve signal quality. In addition, a multi-step fitting procedure is proposed that uses χ^2 weighting to reduce the effect of false angles obtained from spurious signal.

References

1. Look et al., Rev Sci Instrum., 1970
2. Henderson et al., Magn Reson Imaging., 1999
3. Nkongchu et al. Magn Reson Imaging., 2005
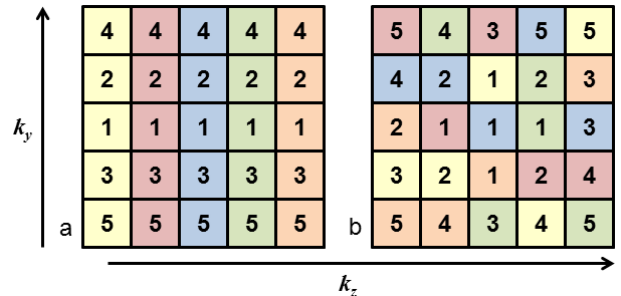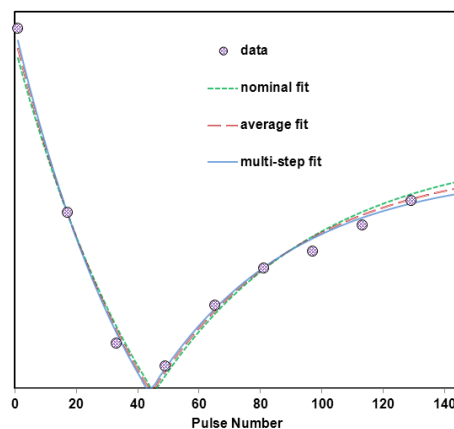4. Deichmann, Magn Reson Med., 2005

Figure 2 The proposed multi-step fitting procedure can yield the lowest χ^2 value.
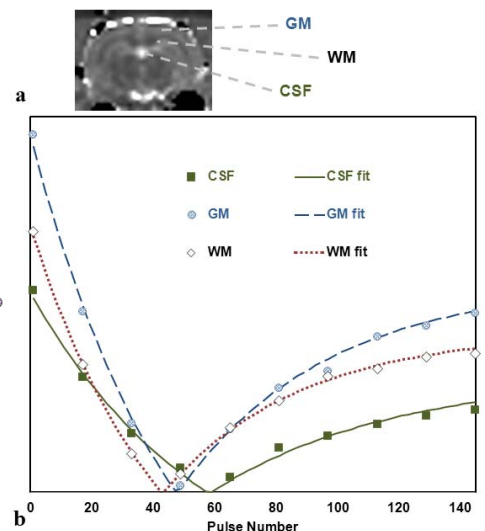

Figure 3 a) T1 map of a rat brain. b) Representative data and their corresponding fitting curves.