Full-Brain T1 Mapping through Inversion Recovery Fast Spin Echo Imaging with Time-Efficient Slice Ordering

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Introduction

Brain water content measurement has important clinical application in detecting brain disorders (1). A linear relationship between the inverse of the brain tissue water fraction and the inverse of T_1 has been found at various magnetic field strengths (1, 2). A full-brain T_1 mapping pulse sequence based on a multi-slice inversion recovery fast spin echo (FSE) imaging (3) is proposed here. Fast spin echo sequence is a fast imaging technique that can provide superior image quality. The scan time is further reduced by a time-efficient slice-ordering technique similar to that proposed by Clare et al. (4).

Methods

The slice-ordering technique is demonstrated here with an example (Fig. 1). Five TI steps (five TI choices for T_1 map generation) are used for the T_1 mapping of 10 slice locations. Each train of slice acquisition starts with a non-selective 180° RF pulse, which inverts spins within the entire sensitive volume of the head transmit coil. After a fixed time delay (the first TI choice for some slices), acquisition starts with a typical multi-slice fast spin echo pulse sequence. After all phase encoding steps are completed with the 1st slice-ordering scheme, data are acquired with the 2nd slice-ordering scheme. Data acquisition continues with the same fashion with other three slice-ordering schemes. The TI increment is equal to the time between every other two slice acquisition lengths, each of which equals to TR divided by the total number of slices. At each slice location, five images at different TI choices are acquired.

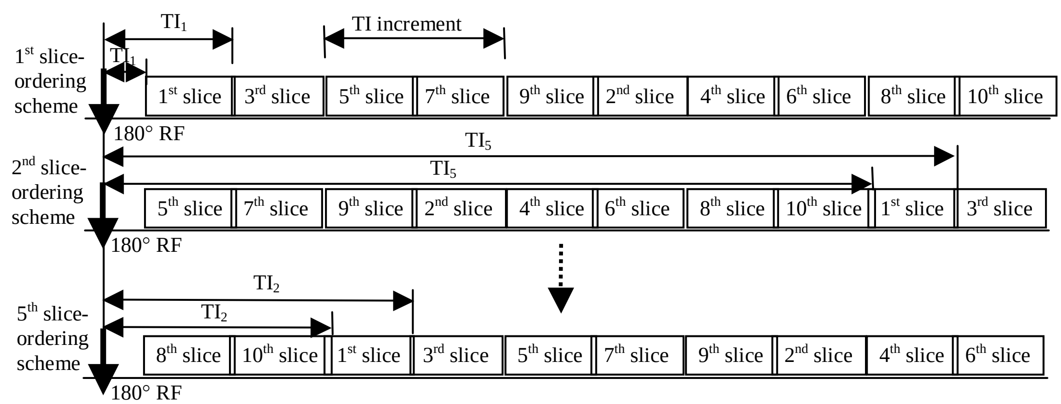

Fig. 1. Three of the five TI steps (TI_1, TI_2, TI_3, TI_4 and TI_5) for the 1st and 3rd slices are illustrated. Five slice-ordering schemes, with three of them shown, are needed to complete the five TI steps.

Perfect 180° spin inversion is often difficult to achieve within the entire sensitive volume of the head transmit coil. To calibrate the effective spin inversion level at each voxel, as part of the full sequence, images are also acquired with the same fast spin echo sequence without the non-selective spin inversion.

This full pulse sequence has been implemented on a GE Signa 3T MR imager and has been verified with phantom studies. Twelve 5-mm slices were acquired from a uniform silicon gel spherical phantom with scan parameters of 12.4 ms TE, 3 s TR, 4 FSE echo train lengths, ± 15.63 kHz receiver bandwidth, 256 × 128 matrix size, 12.4 ms echo spacing and 24 cm field of view (FOV). Slices were acquired in an interleaved fashion resulting with six TI choices (20 ms, 520 ms, 1020 ms, 1520 ms, 2020 ms and 2520 ms for half number of slices, and 270 ms, 770 ms, 1270 ms, 1770 ms, 2270 ms and 2770 ms for the other half). False-position interpolation was used to calculate the T_1 values at the four middle TI choices based on the ratio of the pixel signal with and without the non-selective spin inversion. Pixel signals acquired from the first and last TI choices were only used for the overall calibration of the spin inversion level. T_1 at each voxel was estimated based on the minimal variation of the T_1 values calculated at the four different TI choices, comparing at different spin inversion levels within the possible range of -0.4 to -1 with a step size of 0.01, where "-1" is equivalent to perfect spin inversion. Twelve T_1 maps were generated.

T_1 maps were also generated from basic spin echo images for comparison. Twelve 5-mm slices were acquired from the same phantom with the same matrix size, receiver bandwidth and FOV, but with 18 ms TE and 2 excitations. Images were first acquired with a proton-density weighted protocol with 3 s TR and then with a T_1 weighted protocol with 1.5 s TR at the same central frequency, and transmit and receiver gains. False-position interpolation was used to calculate the T_1 values based on the ratio of pixel intensity between proton-density weighted and T_1 weighted images.

Results and Discussion

From all 12 slice locations, the T_1 value from the proposed multi-slice inversion recovery FSE sequence was estimated to be 1143 ± 54 ms, and the T_1 value from the basic multi-slice spin echo sequence was estimated to be 1192 ± 86 ms. They are in good agreement with each other. The above T_1 mapping technique based on multi-slice inversion FSE acquires high-quality images with an efficient usage of the scan time. These images allow accurate T_1 calculation, and thus can eventually be applied for accurate brain water quantification. We are still actively evaluating different T_1 calculation methods for the proposed pulse sequence.

References

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