Spatial localization of relaxation dispersion by field-cycling with one-dimensional projection

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Purpose

Field-cycling MRI[1] differs from conventional MRI in that the normally fixed magnetic field strength B_0 is switched up or down during an experiment. In this way, field-cycling provides access to endogenous information not accessible to standard MRI, such as the extent of T_1 relaxation efficiency enhancement at certain NMR frequencies due to interactions between hydrogen and nitrogen nuclei in proteins and other biopolymers. T_1 dispersion measurement by imaging is associated with lengthy scan times due to the requirement to encode spatial information in two or more dimensions at each magnetic field strength of interest. Recent approaches to accelerated T_1 dispersion measurement include signal localization by PRESS[2] and fast imaging[3]. In this abstract a third approach is introduced, namely T_1 dispersion measurement with one-dimensional projection.

Methods

The imager used for the experiment is a home-built, whole-body field-cycling MRI system[4] with a permanent magnet providing the 59 mT vertical detection field. A resistive saddle-shaped magnet is installed coaxially for field-cycling by field compensation, leaving a clear bore of 65 cm. The imager is controlled by a commercial MRI console (MR Solutions, UK).

The pulse sequence (Figure 1) consists of an adiabatic full passage inversion RF pulse, followed by an evolution period T_{evol} at the magnetic field strength of interest B_{0E}; this evolution period stepped through values between approximately 0.1 and 3 times the sample's T_1. Delays T_a and T_d are required for magnetic field stabilization. The magnetization profile along the axis of a single field gradient G_1 is recorded during gradient echo readout. The sequence can be made slice selective by replacing the hard 90° RF pulse with a frequency selective pulse and second gradient. The entire sequence is repeated with different values of B_{0E} to collect IR data over the desired range (e.g. 20 to 60 mT at 1 mT intervals). The Fourier transform of the recorded data is used with a model[2] of the magnetization's behaviour to determine T_1 at each field step. Mono-exponential relaxation and split-ramp timings are assumed.

Results

The pulse sequence was applied to an array test object, which could represent biological tissue with two different T_1 dispersions. The array consists of a 125 mL sample bottle containing 2.2 mM $CuSO_4$ in deionized water and a syringe of 25 mL of heat-treated hen egg albumen, the samples selected to give a similar T_1 at 59 mT. Using the pulse sequence, the T_1 dispersion of the array was measured at three field strengths in three minutes (Figure 2). Over the measurement range of 40 to 58 mT, the T_1 of the $CuSO_4$ sample barely changed, while the egg white T_1 declined steeply at 49 mT, a field strength known to correspond with an NQR transition frequency.

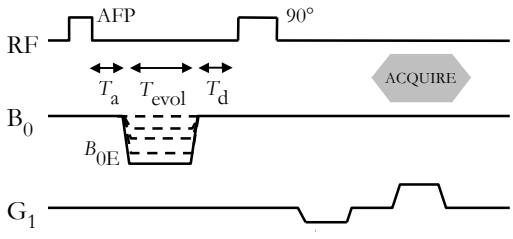

Figure 1: 1D T_1 dispersion pulse sequence

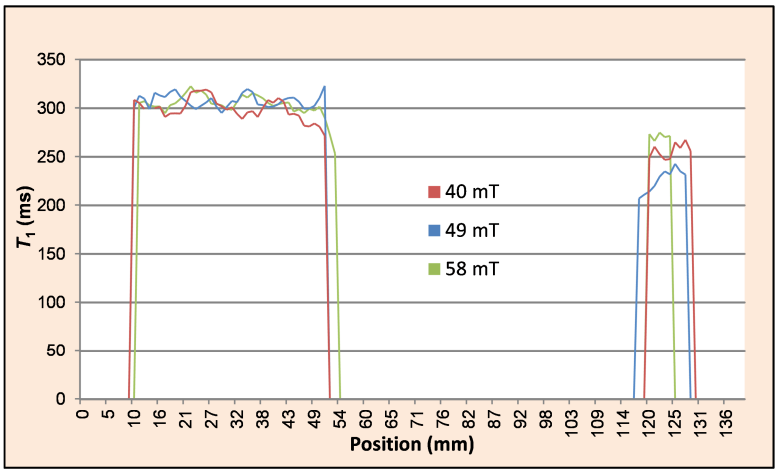

Figure 2: 1D T_1 dispersion profile for an array of $CuSO_4$ (left) and albumen (right)

Discussion and Conclusion

A sequence was demonstrated for measuring T_1 dispersion in a single spatial dimension. The applicability of the sequence depends on tissue homogeneity at depth. The relatively minor extension to a multi-exponential IR model would provide a better fit for the multiple components likely to be found in tissue. Recent work has found changes in T_1 dispersion linked to pathology, e.g. osteoarthritis[5]. In practice, the sequence might be used to rapidly locate characteristic T_1 dispersion for subsequent inspection by other methods.

References

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