Spin Echo Magnetisation Transfer EXperiment (SEMTEX): a rapid, quantitative technique for magnetisation transfer imaging

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Introduction

There are a number of MR techniques available for the characterisation of magnetisation transfer (MT) properties in clinical settings. The most common approach is one in which a single long, off-resonance pulse is emulated by a series of short pulses to selectively saturate the macromolecular bound proton pool, yielding only qualitative MT contrast. A number of methods exist for generating quantitative MT [1-6], which employ varying degrees of complexity and scanning times. We have implemented a quick and simple method for creating quantitative MT contrast using on-resonance pulsed saturation. Here we present the SEMTEX (Spin Entrapped Magnetisation Transfer Experiment) sequence and compare the method applied in phantoms and in vivo with a standard, widely accepted quantitative MT method [1].The sequence is simple to program and execute on clinical systems.

Methods

The SEMTEX sequence (Figure 1) consists of a train of 180° pulses, followed by an imaging module. The inversion pulse train saturates, and subsequently maintains saturation of macromolecular protons, whilst allowing liquid pool spins to invert and decay by T_1. The decay rate observed during the 180° pulse train is a function of T_1 and signal loss due to MT (Figure 2). Overall decay is denoted $T_1^{effective}$. The MT component is extracted as a rate difference between the observed R_1 and $R_1^{effective}$.

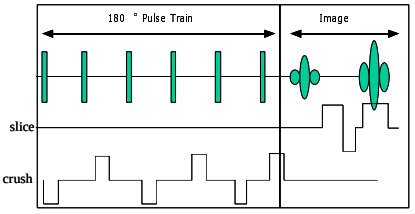

Figure 1: The SEMTEX sequence: a timing diagram illustrating the two principle components: inversion pulse train & image module.

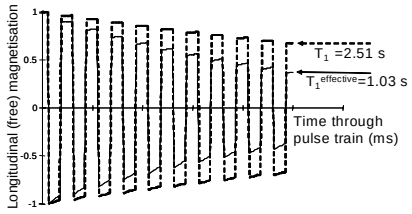

Figure 2: Simulation of T_1 decay during the 180º pulse train of the SEMTEX sequence. T_1 is decreased in the presence of MT effects (denoted $T_1^{effective}$).

The SEMTEX sequence was compared with a conventional quantitative MT sequence [6] using a 300MHz horizontal bore magnet interfaced to a Varian Inova console (Varian Inc., Palo Alto, CA). Seven phantoms consisting of 1-7% (w/v) agarose, a control consisting of 0.3mMolar $NiCl_2$, and an isofluorane anaesthetised normal male Wistar rat were tested. Data were collected using the conventional MT sequence with a 5sec CW pulse applied at 4 RF amplitudes and as a function of 18 offset frequencies. MT parameters were generated by simultaneous fitting of all data, emulating the work of Henkelman *et al* [6]. SEMTEX data were collected during the same experiment, acquiring four images employing 0, 2, 4, and 8 inversion pulses (200µs hard pulses with inter pulse delay of 50ms). The imaging module in both cases was a fast spin echo sequence (5 echoes, 15ms echo spacing, 128x125 matrix, FOV 3.5 by 3.5cm, 1mm slice thickness, TR 3sec), acquisition time of approximately 90seconds per image. $T_1^{effective}$ maps were calculated by exponential fitting of the SEMTEX data, andT_1 maps by exponential fitting of spin-echo data acquired at inversion times from 0.01-1.4s (TR=5s).

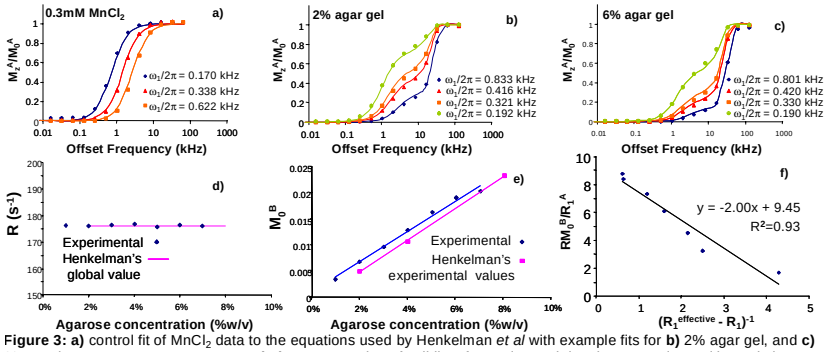

Figure 3: a) control fit of $MnCl_2$ data to the equations used by Henkelman *et al* with example fits for **b)** 2% agar gel, and **c)** 6% used to generate MT parameters. **d-e)** Demonstration of validity of experimental data by comparison with Henkelman's data. **f)** Linear correlation between SEMTEX $R_1^{effective}$ data and classically determined MT data.

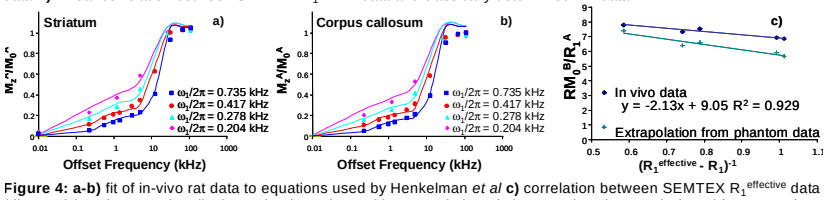

Figure 4: a-b) fit of in-vivo rat data to equations used by Henkelman *et al* **c)** correlation between SEMTEX $R_1^{effective}$ data (diamonds) and conventionally determined MT data, with extrapolation of phantom data (crosses) plotted for comparison

Results

MT parameters were derived by fitting to the equations used by Henkelman *et al*. The experimental fit and comparison with published data are illustrated in Figure 3. Considering the two pool model describing the MT phenomenon, liquid spins lose longitudinal magnetisation to the bound pool at a rate dictated by the exchange rate (R) between the bound and free pools. R is modified by the relative population of the bound pool to yield the pseudo first-order rate constant RM_0^B. The signal losses due to MT processes are in competition with the rate at which magnetisation relaxes by T_1 in the liquid pool (R_1^A). Pathological conditions often illustrate changes in observed T_1 relaxation rates, thus, the indicator of the amount of MT occurring considered most meaningful in this work is the ratio of these two rates (RM_0^B/R_1^A).

Figure 3(f) presents the relationship between RM_0^B/R_1^A and the SEMTEX measure of MT (rate difference between observed R_1 and $R_1^{effective}$), which are seen to be highly correlated. Deviation from a linear fit may represent differing experimental conditions such as accuracy of pulse calibration between experiments. However, the closeness of fit suggests that SEMTEX data can be scaled to yield quantitative MT images. Figure 4 presents the same data for regions of interest in the rat brain.

Conclusions

We have demonstrated that the SEMTEX approach produces image contrast which is related to quantitative MT parameters in phantoms, and *in-vivo* which are strongly correlated with results from the standard quantitative MT approach. The SEMTEX sequence is a simple extension of conventional imaging and should be straightforward to implement in a clinical setting where the speed of the method will be of advantage.

References

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