Dependence of T1 and T2 on high field strengths in doped agarose gels; facilitating selection of composition for specific T1/T2 at relevant field.

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Synopsis

Paramagnetic doped gel phantoms are widely used for evaluating MR procedures. Although copious data on relaxation properties for such gels exists at low-field (<100MHz) this is not the case at high-field. Gel compositions of 0.1 to 6%w/v agarose with 0.001 to 6mMol $dm^{-3}NiCl_2$, were measured with inversion-recovery and spin-echo sequences at 85 to 500MH_z.

Relaxation rates are largely independent of each other: T_1 principally [$NiCl_2$] dependent, T_2 [agarose] dependent. Plots of T_1. T_2 and composition are similar at each field, whereas T_1 and T_2 versus field illustrate mechanistic change between 300 and 400MH_z, preventing simple extrapolation from low-field data.

Introduction

Phantom studies are an important tool for evaluating field homogeneity, stability, and a range of spectrometer performance related parameters, particularly during sequence development and experimental set-up. Gel phantoms offer structural stability and the possibility to independently manipulate T_1 and T_2 to achieve a test object that closely matches the *in vivo* properties of tissue[1]. Literature data on relaxation in doped agarose gels covers only low field strengths making it potentially difficult to predict optimum composition for high-field work. As increasing numbers of high-field magnets are in use for both human and animal studies, this current abstract examines the dependence of relaxation times on magnetic field strength in doped agarose gels for frequencies between 85 and 500 MHz.

Methods

Agarose gels were produced at concentrations of 0.1, 0.5, 1, 2, 3, and 6% (w/v), with the concentrations lower than 0.5% failing to produce solid gel. The agarose was dissolved in double distilled water and $NiCl_2$ was added (concentrations of 0.001, 0.1, 1, 3 and 6 mMol dm^{-3}). The solution was then heated until the sol turned from cloudy to clear and then allowed cool to a gel at room temperature[1].

Longitudinal relaxation was measured with an inversion recovery sequence using inversion times ranging from 0.01 to 1.4 seconds. T_2 was determined using a spin echo sequence with echo times between 0.02 and 0.16 seconds. Measurements were made at 85, 300, 400, and 500MHz using either Bruker Avance (85 and 500MHz) or Varian Inova (300 and 400 MHz) spectrometers.

Results

Figure 1 shows the relaxation data for measurements at 300MHz. As expected T1 and T2 are largely independent of each other: T_1 is principally determined by the amount of paramagnetic ion present, and T_2 is primarily a function of the extent of gel network established (agarose concentration).

Figures 2 and 3 illustrate the relationship between T_1 and T_2 relaxation rates and field strength. Data for all $NiCl_2$ and agarose concentrations showed the same overall profile plots. The T_1 and T_2 data show an interesting transition between 300MHz and 400MHz. The T_1 relaxation mechanism is notably influenced by field strength with T_2 less dependent.

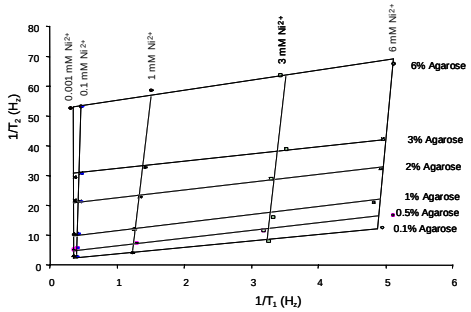

Fig 1: T1 and T2 relaxation rates for mixtures of Agarose gel and Nickel Chloride at 300MHz field strength.

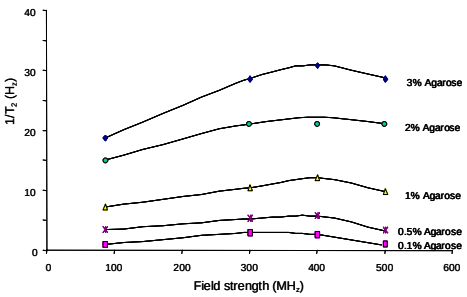

Fig 2: T2 relaxation rate as a function of field strength for a range of Agarose concentrations at 0.1mM Ni^{2+}.

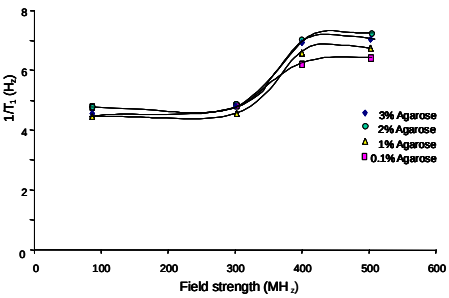

Fig 3: T1 relaxation rate as a function of field strength for a range of Agarose concentrations at 6mM Ni^{2+}.

Conclusions

Figure 1 provides a useful method for selecting the appropriate concentration of Agarose and Nickel Chloride to create a phantom with required T_1 and T_2 values at 300 MHz. A similar relationship was observed at the other field strengths studied.

This data also provides illustration of an interesting trend between T_1, T_2 and field strength. Figures 2 and 3 show that T_1 and T_2 rates generally increase with increasing field but the change does not follow a simple trend. The data suggest there may be a change in T_1 relaxation mechanism occurring between 300MHz and 400MHz affecting a sharp increase in T_1 rate. These changes were evident throughout the range of Nickel Chloride concentrations examined, with no apparent link between the extent of transition and concentration.

These plots are not intended to imply a functional relationship between T_1 and T_2, but to facilitate the selection of an appropriate concentration of agarose and Nickel Chloride to create phantoms with required T_1 and T_2 values at the relevant field. The trends illustrated at the higher field strengths show that T_1 and T_2 relaxation mechanisms change in such a way that extrapolation from the low field data is insufficient to easily predict composition required for particular T_1/T_2 for preparation of experimental phantoms.

[1] Mitchell, M. D., Harold, L., Axel, L. & Joseph, P. M. Agar as a Tissue Equivalent Phantom Material for NMR Imaging. Magnetic Resonance Imaging **4**, 263-266 (1986).