Field Dependence of the Bright Fat Effect in Fast Spin Echo Imaging: Theory and Experiment

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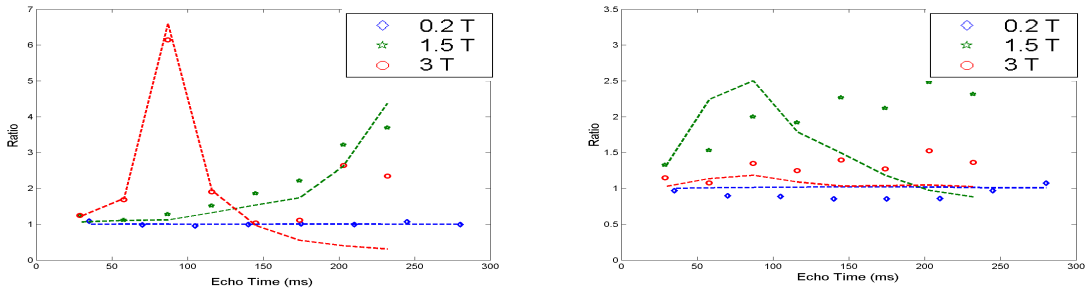
Synopsis: If J-coupling is primarily responsible for the bright fat effect in fast spin echo (FSE) imaging (1-3), then predictions regarding its field strength behavior, largely unexplored to date, may be tested as the ratios of relevant chemical shifts to J coupling constants vary. Namely, for clinically low (0.2 T) and high (3.0 T) fields, the bright fat effect is expected to vanish while at intermediate fields around 1.5 T a pronounced bright fat effect is predicted. These predictions are tested and verified in corn oil and 2,3-dibromothiophene (DBT) samples.

Introduction: For equivalent echo times at 1.5 T, studies have shown that short vs long echo spacing FSE sequences result in bright vs dark fat signals, respectively, a phenomenon known as the bright fat effect. The phenomenon is generally attributed to J-coupling among the lipid protons though direct proof remains unavailable (1-3). At clinically relevant field strengths from 0.2 T to 3 T, however, the regime of J-coupling changes from strongly coupled to weakly coupled as the ratio δ/J varies. We demonstrate experimentally and theoretically how this variation results in minimal bright fat effects at very low and very high clinical field strengths while at intermediate field strengths around 1.5 T, short vs long echo spacings result in fat signals that differ by a factor of 2 or more at equivalent effective echo times.

Methods: Two clinical FSE sequences were applied to corn oil and the AB system DBT, at 0.2 T, 1.5 T and 3 T. One sequence used approximately 16 ms echo spacings and a 16 echo train length (ETL) while the other used echo spacings around 32 ms and an 8 ETL. Images were acquired at each of the 8 common effective echo times from the two sequences and the ratios of the signal intensities in oil and DBT were evaluated from the short vs long echo spacing sequences. These ratios were compared with quantum mechanical calculations (1) of this ratio for an $A_2B_2C_3$ system for corn oil (J_{AB} = 6 Hz, J_{AC} = 0 Hz, $\delta_{AC} = \delta_{AB}$ = 0.5 ppm) and an AB system for DBT (J = 6.6 Hz., δ = 0.22 ppm).

Results: The figure shows the experimental and simulated (solid lines) ratios for DBT (left) and corn oil (right) at each field strength. At 0.2 T the ratios in both samples hover about 1 indicating no bright fat effect while at 3 T there is a modest bright fat effect in corn oil and one pronounced, predicted effect around the 100 ms TE in DBT. At the intermediate field strength of 1.5 T the bright fat effect becomes quite pronounced in both samples as echo time increases. At all echo times and field strengths, experimental DBT ratios agree well with the simulations while at long echo times the 1.5 T simulations of corn oil underestimate the experimental bright fat effect.



Discussion: Overall, the prediction that "low" and "high" clinical field strengths minimize the bright fat effect, which in turn is pronounced at the intermediate field strength is upheld by experiment. The AB spin system and known J and δ constants for DBT result in excellent agreement between theory and experiment. Use of an $A_2B_2C_3$ system for corn oil, however, only models the spin topology of the last three moieties in the hydrocarbon chain. This feature along, with a lack of a precise knowledge of the coupling constants, stimulated echo effects and a neglect of differential relaxation times among the lipid protons in our model most probably account for the underestimation of the bright fat effect in corn oil at long echo times at 1.5 T. The main conclusion remains, however, that only at intermediate clinical field strengths is the bright fat effect most pronounced. Thus only at intermediate field strengths can this effect be potentially useful as a fat/water tissue discrimination mechanism whose benefits (1) are an independence from differential relaxation and/or chemical shift and susceptibility variations that can hamper the more common fat/water discrimination techniques such as short tau inversion recovery (STIR) and chemical shift suppression methods.

References:

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