Flip Angle Variations in PRESS at 4.7 T: Application to Glutamate

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Introduction

Most spectroscopic imaging sequences use soft pulses to perform slice selection. Because of their non-uniform excitation profile for a given slice, the distribution of flip angles across the slice will influence the line shape of a given metabolite [1]. In addition, the human head has similar dimensions to the radiation wavelength at 4.7 T (200 MHz), and therefore wave superposition effects also contribute to the RF distribution [2]. For a given pulse flip angle, it has been shown that the actual flip angle in the brain can vary up to 60% less than the intended amplitude near the edge of the brain [3]. In a PRESS spectroscopy sequence, these RF distributions are expected to have a simple influence on singlet resonances, altering their peak amplitude according to the deviation of the flip angle from the normal 90° – 180° – 180°. However, signal variations resulting from flip angle deviations may be more complicated in strongly coupled spin systems. The effects of flip angle deviations were investigated both theoretically and experimentally at 4.7 T, particularly for the strongly coupled glutamate system (AMNPQ), and creatine an uncoupled spin system.

Methods

Experiments were performed on a spherical phantom containing 50 mM each of cr and glu at 4.7 T using a quadrature birdcage coil for transmission and reception. For each spin system, a PRESS pulse sequence was simulated using an in-house software package (Thompson) designed to accommodate arbitrary spin systems including the effects of strong coupling [4]. The program breaks up the pulse sequence into several segments with individual Hamiltonians, and produces density matrices for each subsequent segment, until the final density matrix is calculated, to produce an FID. The slice-selection pulses were replaced by hard pulses for ease of simulation. Creatine (cr) and glutamate (glu) were simulated with echo times of TE_1 = 20 ms and TE_2 = 90 ms. These optimized timings were chosen to simplify the line shape of the glu PQ multiplet and produce 100% yield compared to a single pulse acquire experiment (ignoring relaxation). Simulation linewidths were adjusted to fit experimental data. In each case, the flip angles were varied according to the PRESS relation $\alpha - 2\alpha - 2\alpha$, and areas computed for the cr A3 and glu PQ peaks.

Results

Figure 1 shows the simulated signal yield for cr and glu for a range of flip angles. For each curve, points were normalized to the $\alpha = 90°$ case which is expected to give 100% yield. Notice the large reduction of the glu area for reduced flip angle, showing that a global correction factor to compensate for signal loss due to RF variation is insufficient. A reduction of 10° in the flip angle results in ~ 20% of the signal being lost for glu compared to ~5 % for cr. Figure 2a shows spectra of simulated data for glu at flip angles of $\alpha = 90°$, 75° and 60° respectively. The spectra are centered on the PQ multiplet at 2.35 ppm. Because of its simple line shape, spectra for cr are not shown here. The corresponding experimental data is shown in Figure 2b. The line shapes are not significantly altered, but signal intensity is dramatically lost when deviating from the $\alpha = 90°$ case.

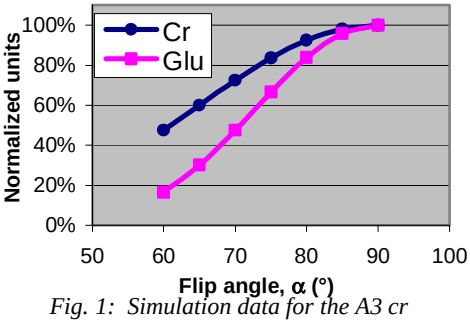

Fig. 1: Simulation data for the A3 cr singlet and PQ glu multiplet at various flip angles.

Discussion

This study illustrates how variations in RF amplitude due to the field-focusing effect and soft pulses affect the strongly coupled spin system compared to a cr singlet. It is important in metabolite quantification in spectroscopic imaging to be aware of differences in percent yield for coupled and uncoupled spins caused by RF variation. Future work may incorporate techniques which are insensitive to RF field inhomogeneities, *i.e.* sequences using adiabatic pulses for refocusing (LASER, [5]).

References

[1] ISMRM 2000 (Denver):1847. [2] Thomas *et al.*, MRM 51:1254-64 (2004). [3] Collins CM, Smith MB, MRM 45:684-91 (2001). [4] Thompson RB, Allen PS, MRM 41:1162-9. [5] Garwood M, Delabarre L, JMR 10:1-7 (1999).

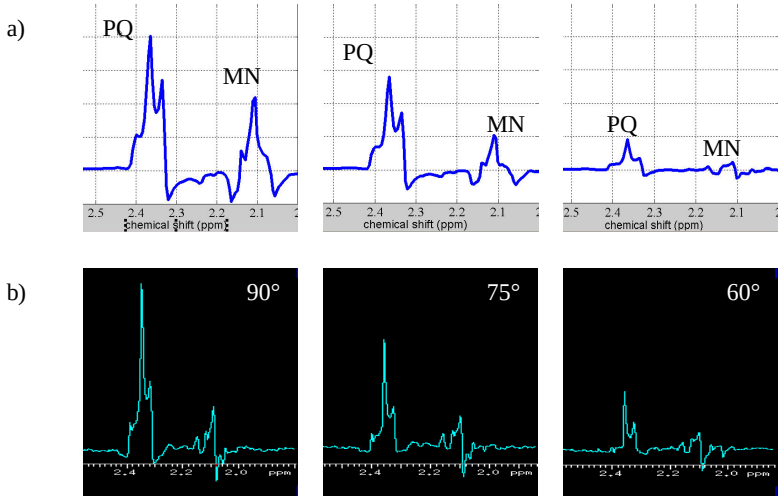

Figure 2: Effect of varying flip angle on the PQ multiplet of glu at $\alpha = 90°$, 75° and 60°, (left to right), for a) simulated data, and b) experimental data. The PQ and MN multiplets are labeled for the simulated data. Line widths for the simulation were broadened to 2.6 Hz to match the experimental data. All spectra were acquired with TE_1 = 20 ms and TE_2 = 90 ms. Other experimental parameters included a voxel size of 20 mm^3, TR = 3000 ms, and 32 averages.