An Optimized Frequency Offset for Refocusing RF Pulses in Measurement of Lactate Using PRESS MR Spectroscopy

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Introduction

One of the well-known artifacts for point resolved spectroscopy (PRESS) is the signal cancellation arising from anomalous J-modulation [1]. This artifact is particularly noticeable for the measurement which involves spins covering a wide range of chemical shifts, for instance, the measurement of Lactate (Lac). In Lac molecule, the methyl protons, a doublet of resonances at 1.3ppm, are J-coupled by a constant of 7 Hz with the methine proton at 4.1ppm. Due to the RF bandwidth limitation, there is a portion of the spins, close to the voxel boundary, which only undergo partial spin echoes in the PRESS and give rise to anomalous modulations for their coupling partners. As a consequence, the measured signals can be severely reduced after summation over the voxel. Several methods have been proposed to deal with this artifact [2,3], including the recently developed method which applies an inner volume saturation to remove the signal from the anomalously modulated methyl spins [4]. In this work, a new approach was presented. It used the frequency offset of 4.1ppm for the refocus RF pulses in conjunction with routinely applied outer volume suppression (OVS), in order to avoid the signal cancellation due to anomalous J-modulation.

Methods

With the frequency is set at 1.3ppm (Fig.1A), the selected voxel is on methyl spins (red box). The methyl spins in the gray region will have a J-modulated phase which is different from that for the rest of methyl spins, because they couple with the methine spins that are outside RF bandwidth for one of the refocus pulses and thus are only partially refocused after the volume selection. The differently phased methyl spins will cancel the normal methyl signal. One the contrary, with the frequency set at 4.1ppm (Fig.1B), the selected voxel is on methine spins (4.1ppm, blue box). The target methyl proton spins at 1.3ppm are in the red box displaced by the chemical shift from the selected blue box. All methine proton spins in the selected voxel are on resonance and fully refocused after volume selection. Therefore, no methyl proton spin within the red box couples with the partially refocused methine proton spin, except there is a portion of the methyl proton spins, denoted by the dotted region, which are outside the RF bandwidth and are to be saturated by the out volume suppression. They have no contribution to the resultant signal, and thus the net methyl signal is enhanced compared to the negative contribution for the offset of 1.3ppm. Experiments were conducted with a braino phantom and a head coil on a 3T GE Excite scanner. The GE's PRESS sequence was used with echo time (TE) =144ms, the bandwidth of refocusing RF pulses =1450 Hz at half height (pulse width = 5.2ms), voxel size = 2.5X2.5X2.5 cm^3, repetition time (TR) = 1.5s and number of average =16. The frequencies of the refocusing pulses are changed to the desired values after the voxels are selected.

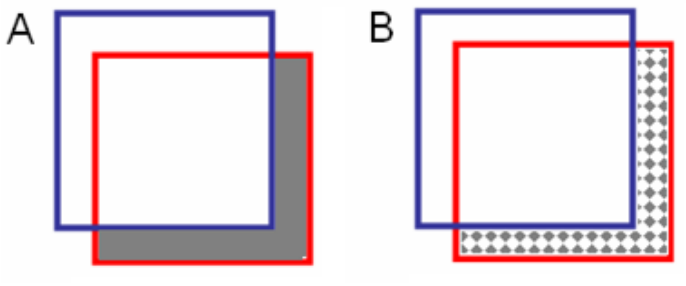

Fig.1. Illustration of frequency offset effect on methyl signal. Red and blue box represent the volume of methyl proton spins (1.3ppm) and methine proton spins (4.1ppm), respectively. (A): offset at 1.3 ppm; (B): offset at 4.1 ppm. Methyl proton spins in gray region in (A) are anomalously modulated and have a negative contribution to the signal in the measurement. Methyl proton spins in dotted region in (B) are saturated by out volume suppression and has no contribution to the signal.

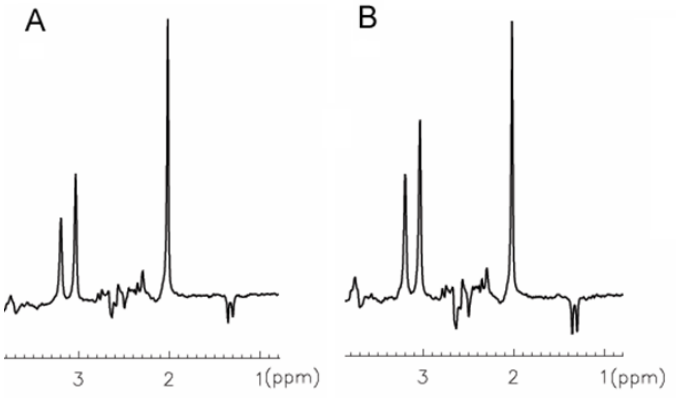

Fig.2. Signal intensity of methyl proton at 1.3 ppm is enhanced by 50% for the frequency offset at 4.1ppm (B) compared to that using the offset at 1.3ppm (A).

Results and Discussions

In Fig. 2, the comparison of the two frequency offsets (1.3 and 4.1ppm) shows that the methyl proton signal of1.3ppm (normalized to NAA at 2.0ppm) was enhanced by ~50% after use of the offset of 4.1ppm (Fig.2B). The intensities of Creatine and Choline were also enhanced, because their resonance frequencies were closer to 4.1 ppm and the out volumes (to be suppressed by OVS) were thus reduced. Any other offset between 1.3 ppm and 4.1 ppm, typically at the middle of 2.5 ppm, would have a mixed result. Our phantom results clearly indicate that the frequency of 4.1ppm is an optimal offset for the PRESS in measurement of Lac; the use of this offset can avoid the methyl proton signal cancellation and enhance the signal in the measurement.

References 1) Yablonskiy DA, et al. Magn Reson Med 1998;39:159–78. 2) Jung WI, et al. J Magn Reson 2001;152:203–213. 3). Kelley DA, et al. J Magn Reson Imaging 1999;9:732–737. 4) Edden RA, et al. Magn Reson Med 2006;56:912-917.