Method for Elimination of Spatial Interference Effects in Lactate CSI

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Introduction: The critical role of lactate as an index of glycolytic metabolism and hence of ischemia in tissues has stimulated the development of many approaches to detect lactate i*n vivo* by nmr spectroscopy [1-3]. Two issues make the reliable estimates of lactate difficult. First, the lactate detection is performed using the doublet at 1.3ppm originated from the methyl protons and it must be separated from a co-resonant lipid signals. Second, spatial interference effects caused by J-coupling can lead to marked loss of signal intensity as well as corruption of the size and shape of the excited region from which the signal is obtained [4]. This phenomenon is substantial at an imaging field of 1.5T and becomes more pronounced at higher field strengths thus making lactate estimates unreliable if not accounted for. Herein we describe a 1D CSI technique which allows separation of lactate signal from lipid and eliminates the artifacts resulting from the spatial interference effects. This technique allows simultaneous detection of other uncoupled metabolites of interest such as choline, creatin, and N-acetyl-asparate.

Theory: Figure 1 shows schematic structure of the pulse sequence. First $\pi/2$ RF1 pulse creates a transverse magnetization in the selected plane. The π-pulses RF2 and RF3, invert magnetization in the plane perpendicular to the first one thus selecting a rectangular region. Phase encoding is used to spatially localize the signal along the length of the region. In addition to the three slice selective RF pulses, the sequence has two frequency selective "editing" π–pulses ED1 and ED2. . The timing diagram of the sequence may be expressed as RF1 – τ – ED1 – τ – RF2 – 4 τ – RF3 – τ – ED2 – τ – ACQ. For lactate molecules one has to consider two different regions similar to described in Ref. 4 arising from the chemical shift difference between the lactate methyl and methine groups. Region 1, where the observed methyl spins and its coupled partners are both refocused by selective refocusing pulses RF2-RF3, and region 2, where only the observed methyl spins are refocused. The role of the editing pulses in Fig. 1 is to refocus the J-modulation of the signal independently in each of these regions by inverting the coupled partner of the methyl protons in each region. If TE and J satisfy the condition TE = 2/J (i.e. τ = 1/4J) and the editing pulses are turned ON, the sequence can be used to invert the methyl doublet for both geometrical regions described above (negative in-phase detection). When the editing pulses are turned OFF, the methyl doublet in both regions will be in phase with uncoupled moieties. Collecting and adding the signal with even number of excitations, when the editing pulses are turned ON for every alternate cycle, will eliminate the lactate signal and leave the signal from uncoupled spins intact. Whereas subtracting the signal from each alternate excitation, will eliminate all the resonances including lipid and leave only the lactate signal.

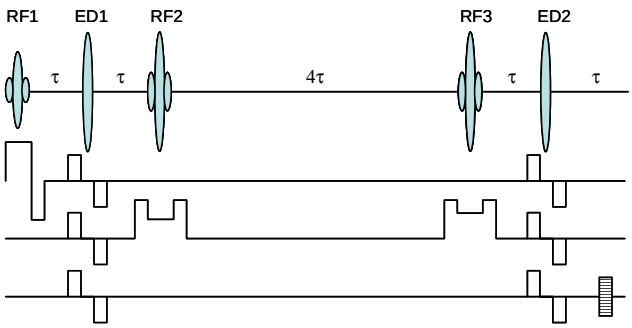
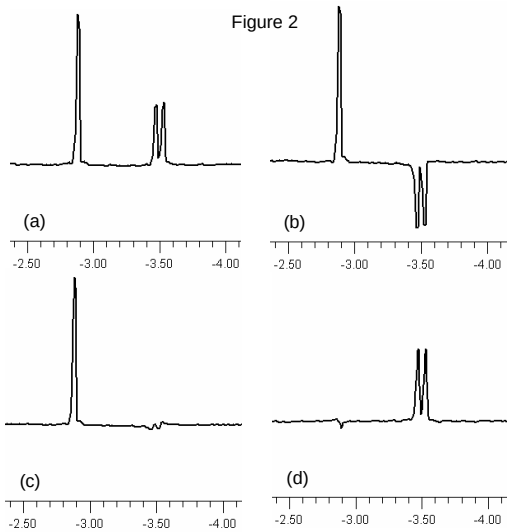


Figure 1

Methods: Data were obtained on a 3T Siemens Magnetom Allegra using a circularly polarized head coil and a phantom provided by the manufacturer containing 100mM lithium lactate and 100 mM sodium acetate. 2 x 2 cm^2 wide rectangular section was excited with 16 phase encoding steps giving a voxel volume of 2 x 2 x 1.6 cm^3. Two acquisitions were acquired in a single experiment. After first order phase correction, the data from two cycles were added and subtracted from each other.

Results and Discussions: The phase corrected spectra from a selected voxel is shown in Figure 2. The singlet corresponds to the acetate signal and the doublet to the signal from lactate methyl group. As expected, both doublet and singlet are in phase in Fig 2a (editing pulses OFF) and in opposite phase in Fig 2b (editing pulses ON). Figures 2c and 2d demonstrate the results of complex addition and subtraction. Addition leads to almost complete elimination of the lactate signal, whereas the subtraction preserves the lactate signal and eliminates the uncoupled acetate signal. Phase correction is needed because the protons, off resonance from the editing pulses, will experience a rotation about the effective field dependent on the frequency difference from the center of the editing pulse. Small residual signal after addition and subtraction may be due to the imperfect phase correction and higher order phase correction may improve the results.

Figure 2



Conclusions: In this work we have demonstrated that this technique can eliminate artifacts resulting from the spatial interference effects and at the same time provide editing of lactate signal. This approach shows promise for improved detection of moieties *in vivo* and can easily be extended to 2D CSI.

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References: 1. Star-Lack J. et. al *J of Magnetic Resonance* (1998); 2. Sotak C. H. et. al. *J of Magnetic Resonance* (1988); 3. Kelley D.A.C. et. al. *J of Magnetic Resonance Imaging* (1998); 4. Yablonsiky D. A. et. al. *Magnetic Resonance in Medicine* (1998)