Quantitative Musculoskeletal MRS Using the Phantom Replacement Method and Phased-array Receiver Coils

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Introduction

Commonly used magnetic resonance spectroscopy (MRS) quantitation techniques such as the internal [1] and external [2] reference methods may be unreliable in the musculoskeletal (MSK) system, due to factors such as variability in the tissue water content, or inhomogeneties of the B_0 and/or B_1 fields. The phantom replacement method using phased-array coils has previously been applied for metabolite quantification in the brain in vivo [3]. This method does not rely on an assumed water content and is compensated for variations in B_1 and coil loading. The purpose of this study is to demonstrate the feasibility of this method in normal human skeletal muscle.

Methods and Materials

Phantom replacement method utilizes phantom metabolites signal collected in a different scanning session. In this study, a phantom with known metabolite concentration (69 mM NAA) was employed as the reference. Its basic principle can be explained in the equation 1.

$$[M]=[P]*\frac{A_M}{A_P}*\frac{n_P}{n_M}*\frac{k_P}{k_M}\frac{TA_M}{TA_P} \qquad (1)$$

With M and P subscripts indicating in vivo metabolites M and reference phantom metabolites P, the meanings of notations are as follows: [M] or [P]: metabolite molar concentrations, A: spectral signal amplitude, n: number of protons in molecules, k: signal damping factor caused spin relaxations, TA: transmitter amplitude in of phased array coils. Ratio of water signal collected from the body coil and phased array coil can be used to scale the body coil's transmitter amplitude, so that the transmitter amplitude of the phased-array coil can be estimated by the reciprocity theorem [3], At 3T, 2 phantoms with Choline (Cho) concentrations in *in vivo* range (5mM and 10mM) were first used to verify this method. Then, Cho concentrations were measured in the quadriceps muscle of 11 healthy volunteers (6 males, 5 females, mean age 35, age range 24-49). All scans were performed with single voxel MRS (PRESS, repetition time 2s; echo time 135 ms, voxel size 2x2x4cc).

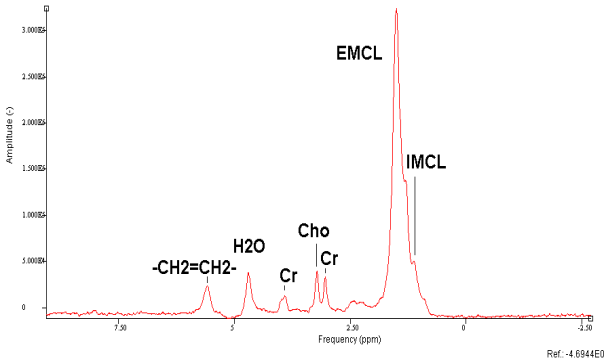

Figure 1. Water suppressed 1H spectrum

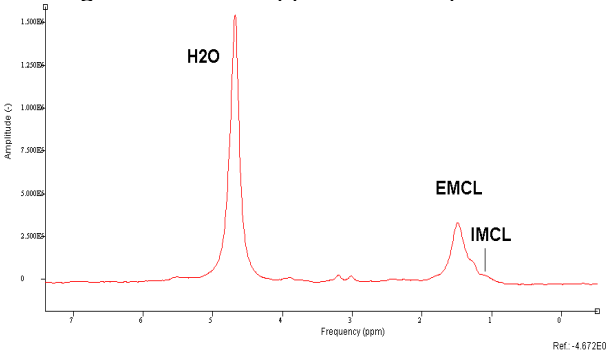

Figure 2. Water unsuppressed 1H spectrum

Phantom	[Cho]p	[Cho]w
5mM	5.02 ± 0.32	4.97 ± 0.28
10mM	9.29 ± 0.43	11.14 ± 0.89

Table 1 Phantom metabolite quantification results in mM/Liter.

In vivo	age	[Cho]p	[Cho]w
Mean	34.8±7	3.41±1.28	4.70±1.82

Table 2 Healthy volunteers muscle metabolite quantification results in mM/Kg.

Results

For in vivo spectra, discrete Cho, creatine, water and lipid peaks were identified in each voxel. A pair of water suppressed and unsuppressed spectra were plotted in figure 1 and 2. After signal acquisition, Siemens MRS quantification package was employed to calculate the metabolites resonance amplitudes. The absolute concentrations measured from the 2 phantoms and 11 subjects are listed in table 1 and 2. [Cho]p and [Cho]w represent result using phantom replacement and internal reference methods respectively. Both the phantom replacement and water referencing methods gave correct estimation of testing phantom metabolites concentration. Appreciable differences in Cho concentrations were found between the two methods in vivo, however. This difference may be due to discrepancies in water content and/or relaxation times of Cho and water in vivo, and will be the subject of further investigation.

Conclusion

Absolute quantitation of muscle Cho levels are feasible using phased-array receive coils. In phantoms the methods give good agreement (within 10% of nominal value), however in vivo Cho as determined by the internal reference technique was appreciably higher, perhaps reflecting differences from tissue water content.

References

[1]: Barker PB and at el, NMR Biomed 1993; 6:89-94. [2]: Ernst T and at el, J Magn Reson 1993; 102:1-8. [3]: Natt and at el, J Magn Reson 2005; 53:3-8.