Localised 13C spectroscopy in Humans with Outer Volume Saturation

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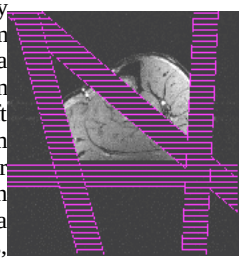
Introduction

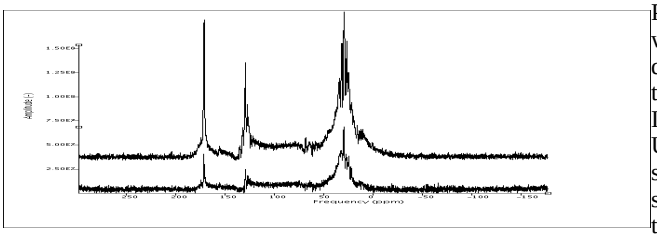
13C NMR spectroscopy is a valuable tool for in vivo assessment of the human glucose and fat metabolism, but intrinsic low sensitivity to 13C nuclei does not enable proper localisation of the signal. Topical pulse-acquire localisation by a surface coil is sufficient for certain applications, e.g. skeletal muscle glycogen quantitation [1], but the strong signal from the adipose tissue decreases the dynamic range for other metabolites (glutamine, glutamate, lactate, etc.) The aim of the study was to implement a non-echo, one-shot method of localised proton decoupled 13C NMR spectroscopy via outer volume saturation [2], within SAR limits, using a combination of a 13C surface coil and a 1H volume coil in a 3T whole body MR system for application to skeletal muscle spectroscopy.

Methods

Measurements were performed on a 3T (Bruker Medspec, Ettlingen, Germany) whole body system equipped with BGA 55 45mT/m gradients. To test the efficiency of the method, phantom experiments were performed on a three compartment phantom. A tube with 20% ethanol sited in a second oil-filled tube is surrounded by a container of saline solution. Saturation slices of 21mm thickness were located to suppress the oil signal while leaving ethanol signal untouched (see left figure). The phantom was placed within the homogeneous volume of the magnet on top of a 10cm linear 13C tuned surface coil transceiver. Phantom and coil were surrounded by a 1H transceiver knee coil for shimming and decoupling. After scout images were acquired, localised shimming in a voxel sited in the inner tube above the surface coil was performed. Preceeding excitation with a 0.15ms block pulse, three slice-selective pulses per saturation slab (WURST shape [3], 2.5ms, 10kHz bandwidth, sub-adiabatically driven) each followed by 2ms spoiling gradients were applied to suppress unwanted signals. WALTZ-4 decoupling during 137ms acquisition was turned on. Repetition time was 5s. The same experimental setting was also tested on three young, lean, healthy male subjects (see right figure). The right calf muscle was placed on top of the surface coil. Saturation slices were placed to suppress subcutaneous fat and bone marrow magnetisation, meaning signal arises mainly from gastrocnemius and soleus muscle. Manual, localised shimming was performed on a voxel placed in muscle tissue above the surface coil. 128 scans were acquired in 11mins. Fatty acid signals were quantified using jMRUI [4], AMARES [5].



Results



Pilot experiments on the three compartment phantom yielded satisfactory results, with unwanted oil signal being suppressed by a factor 5. Chemical shift displacement artefacts could be minimised by the large, flat excitation profile of the WURST pulse.

In vivo performance was strongly dependent on the quantity of adipose tissue. Using a series of 4 to 6 (dependent on the subjects' geometry) outer volume supression slices fatty acid signals of CH3 (~13ppm to COOH (~172ppm) (see spectra, top nonsuppressed, bottom suppressed) arising mainly from adipose tissue were suppressed by a factor of 3.5 to 6 in young volunteers over the whole spectral region, while creatine resonances at ~38ppm, ~54ppm and ~158ppm were left unaffected, within the standard deviation given by the level of noise in the spectra. A slight reduction of linewidths of ~5Hz could be observed as well. Quantitation of signals close to fatty acid resonances, mainly between 20 and 40ppm, such as important resonances of glutamine ~27, 32ppm, glutamate ~28, ~34ppm, alanine ~17ppm, lactate ~21ppm is easier and more accurate. SAR values can be estimated to be ~0.83W/kg for decoupling and ~0.75-1.13W/kg for saturation per repetition, and are within FDA guidelines. Other small resonances, especially in regions 40-60ppm and 173-190ppm could be observed, but could not be assigned unambiguously.

Conclusions

The presented method is suitable for acquiring 13C spectra over 200ppm in one shot combining the sensitivity advantages of surface coils and localised spectroscopy. It needs neither refocusing pulses, which show poor performance with surface coils, is not T2 dependent, nor uses an add/subtract cycle as in the ISIS scheme. Furthermore, the VOI is defined primarily by the sensitive volume of the surface coil, so SNR is higher than in single voxel spectroscopy, yet one can remove unwanted signal. The quality of spectra obtained by this method indicate it to be feasible for application in in vivo human studies of skeletal muscle metabolism.

References

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