Multi-Echo based Correlated Spectroscopic Imaging

J. Furuyama[1], and M. Thomas[1]
[1]UCLA, Los Angeles, CA, United States

Introduction – Despite the many advantages of Chemical Shift Imaging (CSI) [1] over ordinary single voxel spectroscopy, its one-dimensional (1D) spectra are still limited by severe spectral overlap, which can complicate quantification of metabolites. Two-dimensional Magnetic Resonance Spectroscopy (2D MRS) aims to alleviate the quantification problems due to spectral overlap by pushing resonances into a second spectral dimension. Despite the improvement in metabolite identification, widespread usage of 2D MRS is hindered by limited spatial coverage. Recently an Echo-Planar Correlated Spectroscopic Imaging (EPCOSI) technique was shown to produce multiple spatially resolved 2D MRS spectra in the human calf muscle in a clinically feasible scan time of 20 minutes [2]. In light of the feasibility, there is still a need to reduce the scan time for further clinical applicability. We propose the use of a Multi-Echo based Echo-Planar Spectroscopic Imaging (ME-EPCOSI) technique, which makes use of spin echoes to collect multiple Echo-Planar Spectroscopic Imaging (EPSI) readouts in a single TR. As a proof of principle, we made use of two different echoes to reduce the scan time to 10 minutes without significant loss of spectral quality from T_2 effects.

Methods – The ME-EPCOSI sequence is shown in Fig. 1. The second spectral dimension is introduced by adding an incremental delay, t_1, between the first 180^0 and the last 90^0 pulses. The ME-EPCOSI sequence was tested on the calf muscle of a healthy male volunteer using a Field of View (FOV) of 16x16cm^2, covered by a 16x16 imaging grid and a slice thickness of 2.5cm, resulting in an individual voxel volume of 2.5cm^3. The following experimental parameters were used, TR/TE/avgs = 1500ms/30ms/1 and 4 preparation scans, resulting in a scan time of 10 minutes. Outer-volume suppression (OVS) bands were used to suppress lipid signals coming from subcutaneous lipids, and a WET sequence was used for water suppression. The spectral bandwidths in the F_1 and F_2 dimensions were 1250Hz and 1190Hz, respectively.

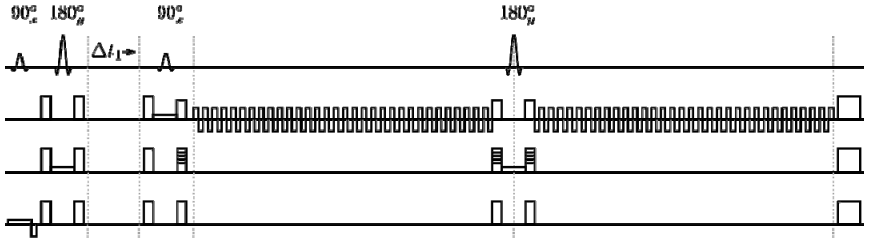

Fig. 1 – Pulse sequence diagram for the ME-EPCOSI sequence

Results and Discussion – Figure 2 shows a T_1-weighted image of a human calf muscle with an overlay of the spatially resolved creatine 3.9ppm diagonal peak. As has been previously reported, the creatine 3.9ppm singlet is expected to split in the tibialis anterior (Fig. 2A) due to a residual dipolar coupling, but no splitting is expected in the soleus muscle (Fig 2B). Both spectra show cross peaks originating from the olefinic protons in both mono- and poly-unsaturated fats at (5.4,2.1ppm) and (5.4,2.9ppm). The presence of intra-myocellular lipids (IMCLs) can be seen from the cross peaks at (5.2,2.8ppm) and (5.2,2.0ppm), which are nicely resolved in the soleus muscle and are also not expected to be present in the tibialis anterior of healthy volunteers. IMCLs are generally difficult to resolve in standard 1D spectral techniques due to spectral overlap, but are nicely resolved in the 2D MRS spectra.

Conclusions – The two-echo ME-EPCOSI has been shown to provide spatially resolved 2D MRS spectra like the single-echo EPCOSI technique, but requiring only half the scan time. As a result, the ME-EPCOSI technique has the potential to be valuable in various clinical studies, such as heart failure or diabetes, where the levels of IMCLs in different muscles can be used as markers for differences in metabolic activity. Just as with RARE imaging, the employment of additional spin-echoes has the potential to further reduce scan time, but care needs to be taken as to avoid significant T_2 effects.

References

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[2] Lipnick S, Verma G, Ramadan S, Furuyama J, Thomas M. Magn Reson Med 2010;64:947–956.

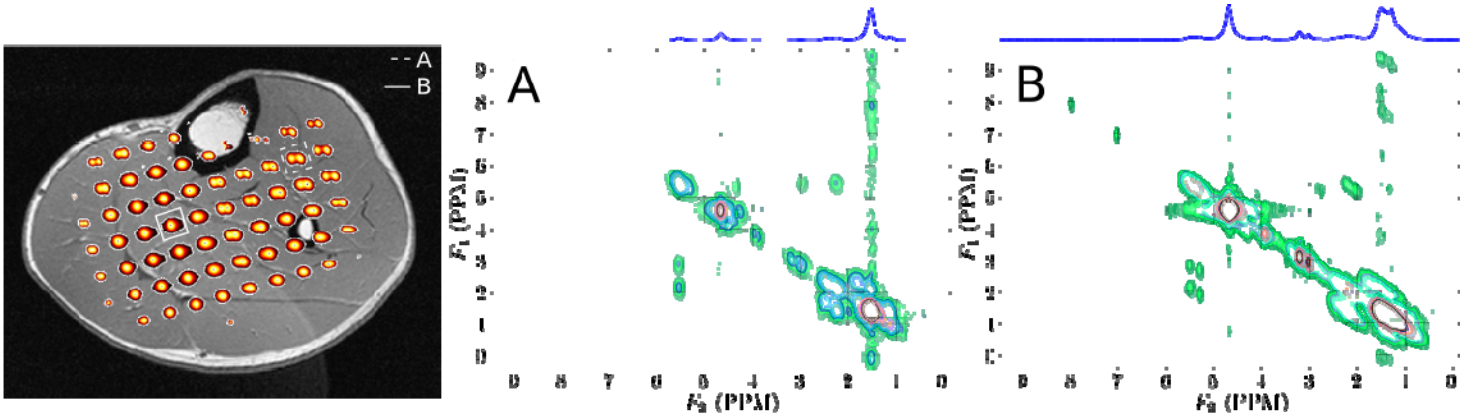

Fig. 2 – 2D spatial profile of the creatine 3.9ppm diagonal peak in the calf muscle of a healthy male volunteer, which shows splitting in the tibialis anterior (A), and no splitting in the soleus muscle.