Echo-Planar based Correlated Spectroscopic Imaging (EP-COSI): Implementation and Evaluation in Human Skeletal Muscle Using a 3T MRI Scanner and a 8-channel Knee Coil.

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Introduction: Multi-dimensional NMR is performed in vitro and ex vivo to characterize tissues through detection of metabolic concentrations and connectivity of 1H protons. The in vivo counterpart, multi-dimensional MR Spectroscopy, has been performed clinically using a single localized voxel with diagnostic potential in the brain, prostate, breast, and skeletal muscle (1,2). However, these studies were limited by the requirement of pre-determination of the volume of interest (VOI). Fast MRS imaging can be achieved using EPI readout [3-5]. We present a novel multidimensional Echo-Planar Correlation Spectroscopic Imaging (EP-COSI) sequence, which utilizes EPI readout combined with phase encoding to obtain spatially resolved 2D Correlation Spectroscopy (COSY) spectral data sets. The EP-COSI pulse sequence is similar to a standard CSI sequence with the final 180^0 refocusing pulse converted into a 90^0 slice selective coherence transfer pulse. The 2D COSY spectra were obtained by iteratively acquiring one dimensional (1D) spectral based echo-planar spectroscopic imaging (EPSI) data sets with incrementally longer evolution times between the refocusing 180^0 and the final 90^0 coherence transfer pulses. The resulting data sets contain all information present in 1D based EPSI with additional resonances that indicated proton connectivity. Our results show that EP-COSI offers sufficient sensitivity to detect creatine, choline, and the j-coupled cross peaks due to saturated and unsaturated fatty acids using an 8 channel phased array knee coil.

Methods: EP-COSI was performed on 5 healthy volunteers (mean age of 30 years) using a 3T scanner (Tim Trio, SIEMENS Medical Solutions, Erlangen, Germany) and an 8 channel phased array knee coil. EP-COSI data sets were acquired from an axial slice located in the central portion of the calf with a TR/TE=1.25s/30ms, using a 32x16 image matrix and a 512x50 spectral matrix with an associated pixel size = 0.84 mL. Outer volume suppression was applied in the out of plane directions to suppress lipid and water signal from outside of the VIO. Even and odd echoes were reconstructed separately using a non-water suppressed reference scan for phase and frequency shift correction (4,5). The total scan time was 16 min for acquiring a 2D spatial/2D spectral MRSI data set.

Results: MRI used for EP-COSI slice localization is shown on the left (Figure 1A). The yellow box indicated the acquired volume and the white box indicates the excitation volume. Shown in the middle (Figure 1B) are the reconstructed signal intensity images of the creatine diagonal peak (F2=F1=3.0) (above) and unsaturated fat cross peak (F2=5.8; F1=2.1) (below). The creatine image clearly shows the outline of the calf muscle with voids where the tibia and fibula are located. There appears to be some bleed from the fat under the skin causing the additional signal in the upper right. The fat image shows high signal in the bone marrow and the fatty layer below the skin. Both images show the same structure as in the MRI and clearly resolve muscle, fat, bone, and marrow. On the right (Figure 1c) are spectra from the marrow inside the tibia (below) and a central calf muscle voxel (above). The spectra show resolved diagonal and cross peaks due to water, saturated and unsaturated fatty acids, choline, and creatine.

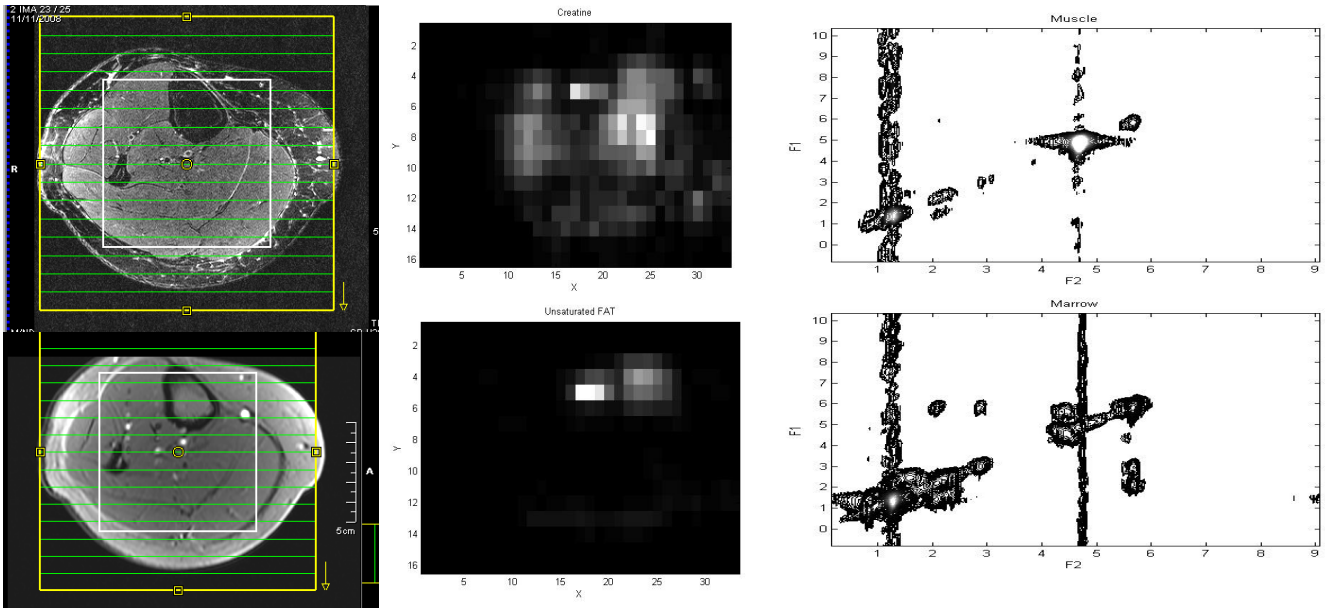

Figure1: A shows the localization used for the EP-COSI sequence. B shows the signal intensity maps of the creatine (above) and fatty acid (below) resonance. C shows the 2D COSY spectra from inside the Tibia (below) and muscle (above).

Discussion: EP-COSI is appealing for studies evaluating metabolic tissue characteristics. This work demonstrates the feasibility of 2D spatial/2D spectral MRSI to differentiate between skeletal muscle, fat, bone, and marrow. This is preliminary work and further research must be done to determine the necessary signal amplitude to detect a given concentration of a metabolite. Once accomplished and the sequence is optimized many more potential clinical utilities of EP-COSI will be clear. Improvements to the data can be accomplished using phased array coils with more channels, optimizing the coil combination, and manipulations of acquisition parameters to minimize scan time and maximize spectral resolution.

References

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