Localized 2D Chemical Exchange Spectroscopy of Human Calf Muscle

M. A. Thomas[1], H. Chung[2], K. Yue[1], T. Venkatraman[3], H. Middlekauf[4]

[1]Radiological Sciences, David Geffen School of Medicine at UCLA, Los Angeles, CA, United States, [2]GE Medical Systems, Waukesha, WI, United States, [3]Albert Einstein College of Medicine, Bronx, New York, United States, [4]Cardiology, David Geffen School of Medicine at UCLA, Los Angeles, CA 90095, United States

Introduction: The effect of irradiated protons associated with immobile macromolecules and membranes on the mobile water protons leads to magnetization transfer (MT) in MT-weighted MRI (1). Similar effect on the metabolites using inversion and saturation transfer has been described recently (2,3). A major goal of this work was to implement a single-volume localized two-dimensional chemical exchange spectroscopic (2D EXSY) sequence on a whole body 1.5T MRI scanner and to record the intra- and inter-molecular dipole exchange of magnetization through 2D spectra in human calf muscle.

Methods: The 2D EXSY sequence included three slice-selective 90^0 rf pulses sandwiched by TE- and TM-crushers. A GE 1.5-T MRI/MRS scanner (General Electric Medical Systems, Waukesha, WI) operating in the LX 9.0 platform with echo-speed-plus gradients (maximum of 30mT/m) was used. A conventional quadrature body rf coil was used for transmitting the rf pulses and a 3" surface coil for signal reception. The following parameters were used to acquire the spectra: TR=2-3s, TE_{min}=22ms, TM=7.5 – 1000ms, Δt_1=1.6ms, Δt_2=0.4ms, 27ml voxel, 1024 complex points along t_2 and 32-45 along t_1, 4-8 number of excitations (NEX) per Δt_1. The study group included 10 healthy volunteers (5 males and 5 females). Healthy controls were aged from 27 to 67 years, with a mean age of 44.4 ± 14.3 years. Before double Fourier transformation, the raw data were transferred to an SGI O2 workstation (Silicon Graphics Inc, San Jose, CA), zero-filled to 2048 and 128 in the two dimensions, and apodized with skewed squared sine-bell filters. The 2D data were processed using Felix-2000 (Accelrys, San Diego, CA).

Results: Shown in Fig.1 is a 2D EXSY spectrum recorded in the calf muscle of a 48yo healthy male using a TM of 7.5ms. The diagonal had the peaks due to the imidazole ring protons of carnosine at F_2=8ppm, and 7ppm, unsuppressed water at F_2=4.8ppm, olefenic and poly methylene protons of lipids at F_2=5.4ppm and F_2=1.4ppm), and overlapping spectral peaks due to carnosine, choline and creatine with the aliphatic protons of saturated and unsaturated fatty acids between F_2=4.5ppm and F_2=0.5ppm). Several COSY-type cross peaks were visible between the olefenic and methylene protons of unsaturated fatty acids at the following locations: (F_2=5.4ppm, F_1=3.0ppm), (F_2=5.4ppm, F_1=2.2ppm), (F_2=3.0ppm, F_1=5.4ppm), (F_2=2.2ppm, F_1=5.4ppm). The dependence of these J-coupled cross peaks over TM was studied by varying TM between 7.5ms and 75ms as demonstrated in Fig. 2(A). The 2D spectrum recorded at TM=300ms in the same volunteer (8NEX/Δt_1 and 40Δt_1) showed the EXSY cross peaks at the following locations: (F_2=4.8ppm, F_1=3.0ppm) and (F_2=5.4ppm, F_1=1.4ppm).

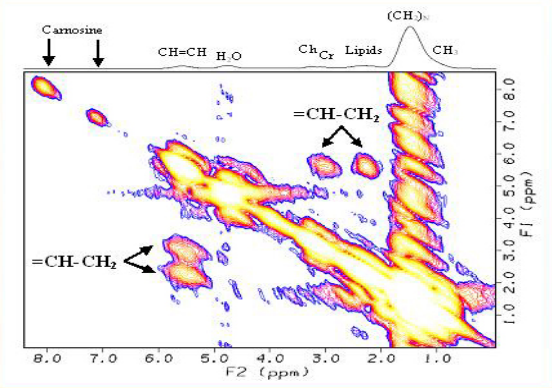

Figure 1. Localized 2D EXSY spectrum recorded in the soleus muscle of a 48 yo healthy volunteer using TM of 7.5 ms (8NEX/Δt_1 and 40Δt_1).

Discussion: In agreement with the previous reports on 2D NOESY (4), 2D EXSY showed J-coupled cross peaks between the lipid protons when TM was varied between 7.8ms and 75ms. This is mainly due to an inability of discriminating the zero-quantum coherences from the longitudinal magnetization during TM. This study is a first time demonstration of intra- and inter-molecular magnetization transfer effects using a localized 2D MR Spectroscopy in vivo. The 2D EXSY spectra showed cross peaks between water and creatine methyl resonance, and also, between the olefenic and methylene protons of lipids, marked as 1 and 2 in Fig.2(B), respectively.

References:

1. Leifbritz D and Dreher W. NMR Biomed 2001;14:65-76.
2. Kruiskamp MJ, de Graaf RA, van Vliet G and Nicolay K. Magn Reson Med 1999;42:665-672.
3. Klaas Jan Renema W, Klomp DWJ, Philippens, et al. Magn Reson Med 2003;50:468-473.
4. Ernst RR, Bodenhausen G and Wokaun A. Principles of NMR in one and two dimensions. Oxford Publications, 1987.

Figure 2. (A) Dependence of COSY-type cross peaks on TM, and B) Localized 2D EXSY spectrum using TM of 300 ms