Functional 2D 31P MRSI in the leg during exercise, using a dual-tuned 1H/31P volume coil

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TARGET AUDIENCE

Researchers interested in muscle physiology, bioenergetics and metabolism and scientists interested in multi-nuclear MRSI.

PURPOSE

To study PCr to Pi conversion during exercise (in the scanner, using tension bands) and recovery, typically non-localized MRS has been used in conjunction with a surface coil placed above the muscle investigated. Recently, 3D mapping of creatine kinase reaction rate in muscles of the lower leg has been demonstrated using a volume coil and the case was made for localization.

The scope of our work is the development of a technique (hardware, data acquisition and reconstruction) which will allow dynamic localized (4D - 2D spatial or 5D-3D spatial; and 1spectral, 1 dynamic) monitoring of the PCr to Pi conversion in the upper leg muscles, during exercise and recovery.

METHODS

A dual tuned 1H/31P volume coil with a diameter of 26 cm and a length of 18 cm was built in house. The coil is equipped with a single channel 1H transceiver and a single channel 31P transmit (Tx) saddle element with separate 4 channels (CH) receive only array. During 1H Tx/Rx mode, 31P receive loops are passively decoupled and 31P Tx loop is actively decoupled. During 31P Tx mode, 1H Tx saddle element is actively decoupled and 31P 4Ch receive elements are passively decoupled. And while in 31P receive mode, both the Tx are actively decoupled. Data was acquired on a 3T Siemens scanner, in the upper leg of a healthy volunteer, above the knee. The upper leg was restrained/immobilized, with the lower leg allowed to perform kicking exercises (restrained by tension bands). Tx voltage/flip angle were optimized at rest for a TR=200ms, using non-localized MRS. One slice (thickness 8cm) was prescribed with a FOV= 24cm x 24cm, and 8x8 2D CSI acquisition, with elliptical encoding. Data was reconstructed to a 32x32 matrix. The elliptical encoding reduces the number of K-space sampling locations from 64 to 29, which results, for the repetition time used, in a SI image being acquired in 5.9seconds. While data is also reconstructed on the scanner (Fig 1), we processed it offline, for doing a sliding window reconstruction and for spectral fitting and quantification.

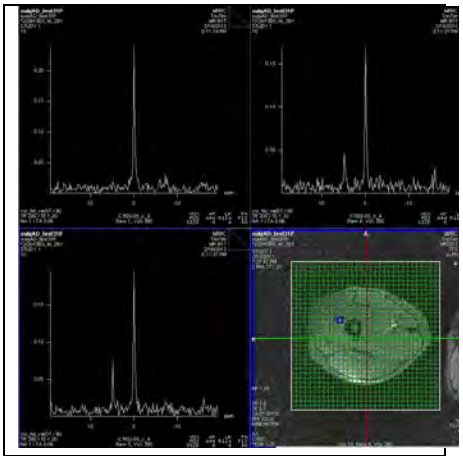

Fig 1:. *Console screenshot, showing the ^{1}H image and spectra for one location in the muscle, for 1st(LT), 3rd (RT) and 5th (LB) measurement, during exercise*

RESULTS:

In Fig 2, the PCr and Pi images corresponding to the five measurement acquired (every 5.9seconds) during exercise, are shown. Using the sliding window reconstruction, an image can be generated for every TR (once the first fully sampled K-space is available), and a movie (not shown) can be created displaying the evolution of PCr/Pi, with a frame for every TR. However, due to the cartesian sampling, for a time evolving signal, the energy in the reconstructed image will be dependent on the initial K-space location, as demonstrated using simulations, in Fig 3.

DISCUSSION AND CONCLUSIONS

The high SNR sensitivity of the custom built 1H/31P volume coil allows for fast 2D 31P spectroscopic imaging during exrcise and recovery. By using a K-space centric sampling acquisition (e.g, spirals/rosettes), the effective time resolution could be increased. Not only the K-space could be sampled quicker than with conventional Cartesian sampling, but the effective time resolution can be increased (better than the time it takes to sample K-space fully). We are in the process of implementing a fast, high-sensitivity Rosette Spectroscopic Imaging (RSI) acquisition.

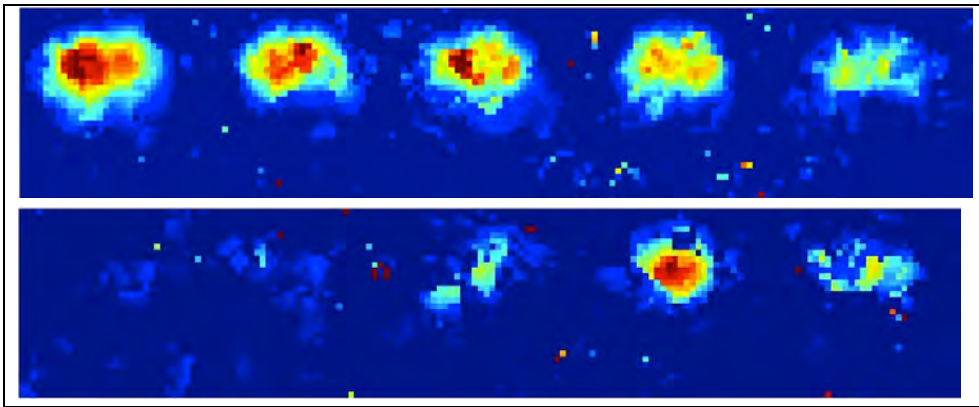

Fig 2: *PCr (top row) and Pi (bottom row), every 5.9 sec (from left to right)*

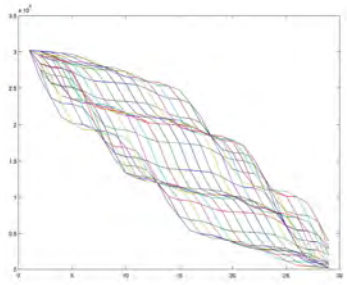

Fig 3:. *Simulations demonstrating that for a time evolving signal intensity, the energy in the reconstructed image depends on the initial K-space location sampled.*