DYNAMIC 31P MRS OF EXERCISING HUMAN MUSCLE IN A 7T WHOLE BODY SYSTEM, WITH STEAM AND SEMI-LASER LOCALISATION

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Introduction The purpose of this work is to examine the applicability of dynamic ^{31}P MRS to a single exercising muscle using gradient based localisation in a 7T whole body scanner. The increased sensitivity obtainable with ultra high field is attractive for ^{31}P MRS with its intrinsically low SNR. Dynamic studies of metabolism are often conducted using non-localised acquisitions using surface coils. Localising by single voxel spectroscopy has the potential of increasing specificity by limiting the VOI to e.g. a single exercising muscle, at the cost of SNR which may in turn necessitate temporal averaging, thus resulting in low temporal resolution. The challenges of dynamic MRS at ultra high field are susceptibility artifacts scaling proportionally with B_0 (potentially annihilating the SNR benefit), particularly in the presence of motion during exercise, limits of RF power and excitatin bandwidth due to increased spectral dispersion.

Subjects and Methods A healthy subject (female, 26 yrs, BMI = 18.7) performed plantar flexion exercise using a custom built ergometer [1] on two study days. Written informed consent to the protocol was obtainded in accordance to the regulations of the local ethics committee. Excitation and reception of RF signals was achieved using a dual tuned loop coil, 10 cm (Rapid Biomedical, D) interfaced to a Siemens 7T whole body MR scanner. For high order shimming the manufacturer's 3D shim was used. A double oblique voxel localised with STEAM and, alternatively, semi-LASER [2] with adiabatic refocusing, was placed in gastrocnemius muscle (Fig. 1), adjusted to the muscle's shape: VOI = 32 / 40 ml, T_R = 8 s, T_E = 17 / 53 ms, RF pulse durations: 3.4 ms / 10 ms, BW~2580 Hz. After 3 min of rest, aerobic plantar flexion exercise was performed for 5 min, inducing significant PCr depletion and intracellular pH shift (see results), subsequently, acquisitions of spectra contimued for 8.5 min, saving each FID separately. PCr was quantified from single acquisitions, 8 spectra were averaged for Pi quantification and pH calculation using AMARES. PCr amplitudes of recovery were fitted to an exponential function of PCr recovery rate constant, end exercise PCr depletion and equilibrium concentration.

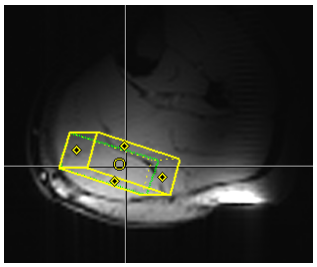

Fig. 1: Position of the VOI.

Results 90° pulses / adiabatic conditions were achieved in the volume of interest placed in the gastrocnemius muscle, at a distance of c. 3 cm from the plane of the coil. Most strikingly, the line width of the PCr was only 6-10 Hz at rest, 10-13 Hz during exercise, and 9-10 Hz after exercise. Narrow lines, high SNR and the absence of DC artifacts the quantification of spectra from single acquisitions, resulting in PCr recovery time courses from a single exercising muscle with a temporal resolution of 8 s (= T_R). See Fig. 2 for a stack plot of spectra and fitted PCr exercise and recovery data. The muscle's average pH was 7.05 (rest), 6.73 (exercise), 7.1 (recovery). In the aerobic exercise bouts of similar intensity, that were studied with STEAM and semi-LASER, PCr was depleted by 54 ± 3 % and 59 ± 3 % with calculated half times of PCr recovery of 44 ± 6 s and 37 ± 4 s. Despite longer T_E of semi-LASER, a c. 1.6 fold increase in PCr SNR compared to STEAM was observed in resting spectra acquired with otherwise equal parameters.

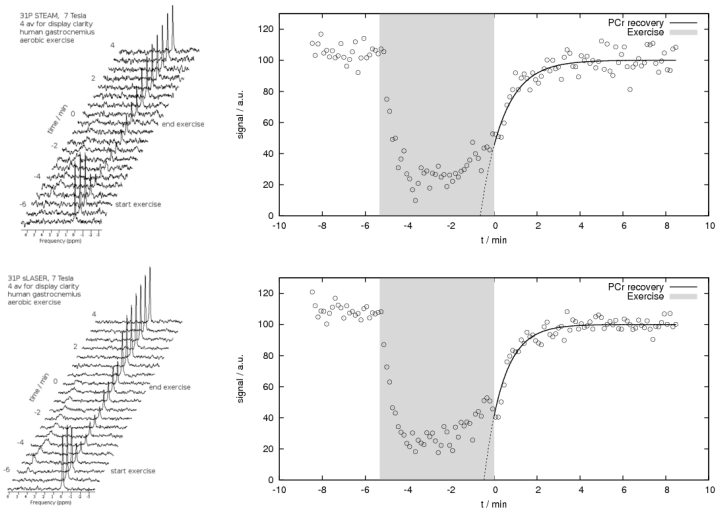

Fig. 2: PCr recovery time course after aerobic plantar flexion exercise measured with STEAM (top) and s-LASER (bottom) localised ^{31}P MRS in a 7T whole body MR scanner. Left: stack plot of spectra (4 avg for clarity of display. Right: fitted PCr time course (no temporal avg).

Discussion and Conclusion We demonstrate that localised ^{31}P MRS can be used to follow metabolic changes with 8s time resolution in a 7T whole body scanner, using STEAM and semi-LASER. The line width of PCr was comparable to previous results at 3T, indicating that the SNR benefit of the high field may be exploited and invested in spatial and temporal resolution, thereby increasing specificity. The band width of the excitation pulse resulted in a chemical shift artifact (% of VOI) for Pi, γ-, α- and β-NTP of 23, 12, 35 and 75 %, which can be reduced by further RF pulse optimisation. The semi-LASER's long T_E is a disadvantage for metabolites with short T_2. While ISIS yields more signal, it lacks the advantage of a single shot sequence and requires 8 repetitions for 3D localisation. LASER based sequences can be advantageous for quantification of *J*-coupled resonances [3, 4], e.g. for ATP.

References 1. Meyerspeer, M., et al. Magn Reson Mater Phy, 2005. 18(5):257. 2. Scheenen, T. W., et al. Magn Reson Mater Phy, 2008. 21(1-2):95. 3. Ouwerkerk. ISMRM 09, #1590, 4. Garwood, M. et al. J Magn Reson, 2001. 153(2):155.