DRESS-localized dynamic ^{31}P-MRS of the exercising human gastrocnemius muscle at 7T

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Introduction: ^{31}P-MRS with rough signal localization by the sensitive volume of the surface RF coil is often used for dynamic measurements during exercise due to its high SNR, simplicity and robustness[1]. Recently, single-voxel localization by a semi-LASER has been proposed to study the heterogeneous impact of exercise on different muscle groups of the calf at ultra-high fields (7T)[2]. Localized measurements showed higher sensitivity to exercise related effects on energy metabolism[2]. This approach, although highly spatially selective has the disadvantage of a prolonged TE leading to a decrease in SNR. The aim of this study was to evaluate an alternative localization method with high temporal resolution and a short TE for the dynamic ^{31}P-MRS. To this extent, the performance of a depth resolved surface coil MRS (DRESS)[3] sequence was assessed in exercising gastrocnemius m.

Materials&Methods: Ten healthy, sedentary subjects (2f/8m, a= 40.8±7.5y) were recruited for this study and underwent the ^{31}P MRS protocol two hours after standardized breakfast. Prior MR examinations maximal voluntary contraction (MVC) of the calf muscle was measured on a home-built device[4]. The volunteers were lying in supine position on an ergometer dedicated to plantar flexion exercise (Ergospect, Innsbruck, Austria) with the right calf muscle placed over a double-tuned surface coil (10cm, ^{31}P/^{1}H, Rapid Biomedical, Rimpar, Germany). Two bouts of dynamic (2 min rest- 6 min exercise- 6 min recovery) examinations (one non-localized and one localized, both based on an FID acquisition with a TE*=0.4ms), with the flexion once every TR (2s) at the same work-load of 25% of MVC, were conducted in a 7T system (Siemens Healthcare, Erlangen, Germany) in a random order. In the localized experiment, the DRESS selection slab (20mm) was placed in an oblique fashion over gastrocnemius muscle avoiding other muscle groups (Fig 1). For spectra analysis jMRUI software with the integrated AMARES algorithm[5] was used. The PCr and Pi signals were fit as single Lorentzians unless the Pi signal split into two peaks. The PCr signal drop, end-exercise and minimal pH, PCr recovery rate constant τ_{PCr}, initial recovery rate V_{PCr} and maximal oxidative flux Q_{max} were calculated. The results from the non-localized and the DRESS-localized experiment were compared by a paired t-test.

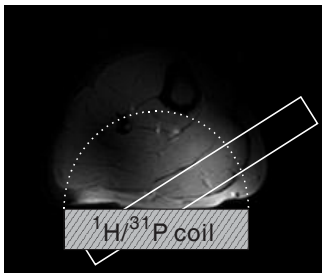

Fig. 1 Localizer image overlaid with localization volumes. Solid line represents the slab selected by the DRESS sequence and the dashed line the approximate coil sensitivity.

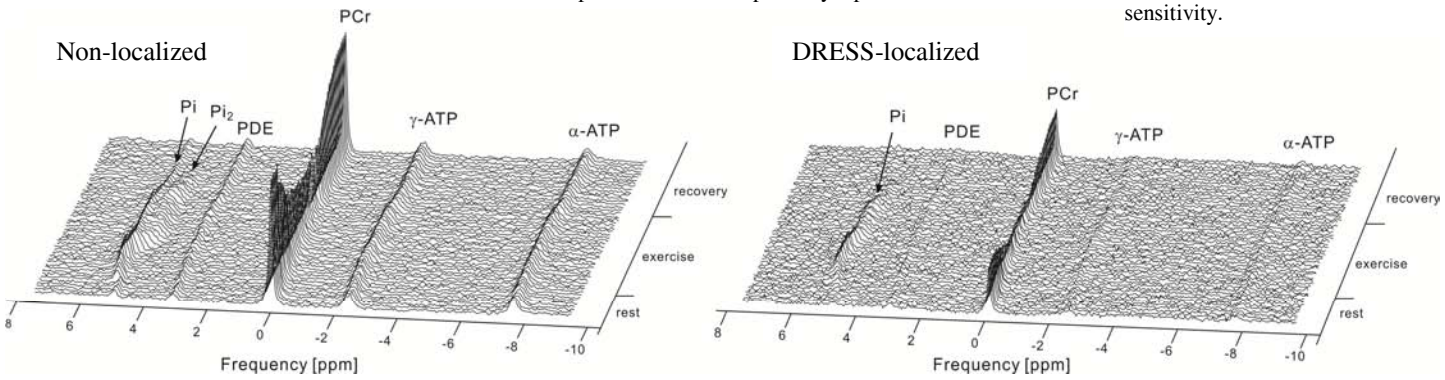

Fig. 2 Time course of the ^{31}P spectra during rest, exercise and subsequent recovery for the non-localized (left) and DRESS localized acquisition (right). The spectra are scaled equally to show the lower signal intensity of the localized experiment. Note the Pi split in the non-localized data.

Results&Discussion: The time change of the ^{31}P signals during plantar flexion experiments for the non-localized and gastrocnemius-localized measurements is depicted in Fig. 2. In consistence with literature on single-voxel localization of the gastrocnemius muscle[6], no splitting of the Pi signal was observed in our DRESS-localized data. On the other hand in the non-localized measurements, the Pi split, suggesting heterogeneous source of the signal was observed in several cases (Fig. 2). Detailed information on the comparison of the measured dynamic parameters is given in Table 1. Significantly higher drop in PCr signal and a trend towards lower τ_{PCr} value are also in agreement with previous findings[2,6]. Although the DRESS selection does not provide localization in all three dimensions and is therefore not suitable for deeper placed structures (e.g. soleus m.), for the gastrocnemius muscle the 1D slab localization seems sufficient. In addition, the FID-based acquisition and low SAR demands of the DRESS sequence offers sufficient SNR for high temporal resolution. Further on, DRESS localization allows quantification of fast-relaxing metabolites (e.g. ATP), which was not possible with single-voxel localization by the semi-LASER.

Table 1. The comparison of the dynamic parameter measured in non-localized and localized experiment. The data are given as mean ± standard deviation; * - p<0.01; § - p<0.05

	non-localized	DRESS-localized
PCr drop [%]	31.20 ± 16.01	43.34 ± 23.41*
pH_end exercise	7.06 ± 0.02	6.96 ± 0.11§
pH_min	7.02 ± 0.02	6.90 ± 0.12*
τ_{PCr} [s]	46.25 ± 14.54	44.38 ± 17.99
VPCr [mM/s]	0.24 ± 0.13	0.35 ± 0.18*
Qmax [mM/s]	0.41 ± 0.14	0.54 ± 0.16*

Conclusion: The localization of the ^{31}P signal from the gastrocnemius muscle during dynamic plantar flexion exercise has been successfully performed by a slice-selective DRESS sequence and compared to a typical non-localized acquisition. DRESS allows for localized dynamic FID acquisition and high temporal resolution at 7T.

References:

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