

ASL in low-intensity exercise at 7T - initial experiences

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Introduction

Blood perfusion is essential for muscle function and tissue health. Vascular complications are a common problem in several diseases like diabetes mellitus. Arterial spin labeling (ASL) represents a truly non-invasive assessment of tissue perfusion using magnetically labeled blood water as an endogenous tracer. This technique can be used to measure dynamic changes in muscle perfusion, e.g. during exercise [1]. The benefits of ASL at 7 Tesla are the increased SNR and increased perfusion weighted (PW) signal due to prolonged T_1 -relaxation times, allowing for longer inflow and imaging times. However there are also challenges at ultra high field arising from B_0/B_1 inhomogeneities, shorter T_2^*/T_2^* times and SAR constraints.

Methods

Measurements in vivo were carried out on a 7T Siemens Magnetom scanner using a form-fitted 2-channel calf coil and an non-magnetic pneumatic ergometer for plantar flexion with adjustable, constant force, both built in-house. Dynamic imaging lasted for 16 min, starting with 2 min baseline measurement, followed by 4 min of exercise (2 plantar flexions with approx. 30 % maximal force after each image acquisition), followed by 10 min of recovery. Two plantar flexions were performed in each recovery period of the T_R . The protocol was repeated to assess the reproducibility of the measurement. For the acquisition of the PW images, a pulsed ASL technique with FAIR labeling scheme and a single shot EPI readout was used [2]. BASSI inversion pulses [3] were implemented for global and slice selective inversion ($\mu=7.2$, $\beta=1214$, $b_0=5$). Saturation pulses were applied after the inversion to reduce the static tissue signal. The imaging parameters were: 64×54 acquisition matrix, GRAPPA factor 2, reconstructed to 64×64 , FOV $160 \times 160 \times 8$ mm³, voxel size $2.5 \times 3 \times 8$ mm³; labeling parameters: 300 ms Q2TIPS duration, inversion slab thickness 18 mm, $T_R/T_E/T_1=6000/30/1600$ ms, effective temporal resolution 12 s. The EPI images were registered using a non-linear approach [4]. The sum over regions of interest (ROI), covering the soleus and gastrocnemius muscle, were calculated resulting in a single signal time course of PW signal for each individual muscle. To improve signal to noise ratio, the time courses were smoothed using a moving average (6 time points).

Results

In Figure 1 the mean PW image (tag-control) of the calf muscle during recovery after the exercise is displayed, clearly showing an increased perfusion primarily in the gastrocnemius muscle. Figure 2a and 2c show the time courses of muscle force (% maximum voluntary contraction) and the T_2^* -weighted (tag+control) signal from a female volunteer (age 23) during run one and two of the experiment, respectively. BOLD data are available from the EPI images. In Figures 2b and 2d the PW signal time courses from both muscle groups is shown. In both runs a transient increase of perfusion in gastrocnemius muscle can be observed after the exercise. The signal intensity in soleus muscle remains mostly unchanged.

Discussion

In this study we demonstrate the feasibility of measuring ASL in aerobic, low intensity exercise with a high temporal resolution and good SNR. The intra-individual reproducibility is high. It is clearly visible that the main load of the exercise is carried by the gastrocnemius. During exercise, motion artifacts dominate the PW images, although EPI themselves are of good quality.

References

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Figure 1. Perfusion weighted image overlaid with an EPI image of the calf during recovery

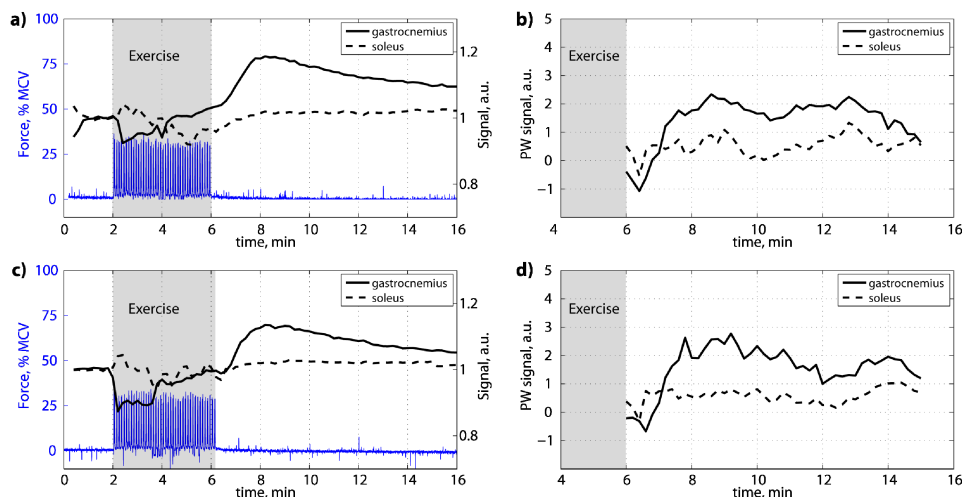
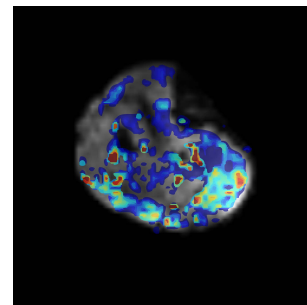


Figure 2. a) T_2^* -weighted signal time course in gastrocnemius and soleus (black) and muscles force (blue) during the 1st run of the experiment. b) Perfusion weighted signal in gastrocnemius and soleus muscles during recovery in 1st run of the experiment. c) and d) corresponding data from the 2nd run.