

# PERFUSION MEASUREMENTS DURING REACTIVE HYPEREMIA IN HUMAN SOLEUS MUSCLE

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**Introduction.** Different imaging techniques have been proposed for the non-invasive assessment of muscle perfusion, e.g. [1-3]. These studies demonstrate the difficulties of perfusion quantification in human skeletal muscle using arterial spin labeling techniques. A major problem is given by the low resting state perfusion and therefore low signal-to-noise ratios. The aim of this study was to evaluate the feasibility of a single-voxel FAIR technique [4] for the quantification of perfusion in the soleus muscle of healthy volunteers during an ischemia/reactive hyperemia paradigm.

**Methods.** Experiments were performed on a whole body scanner at 3 Tesla (Magnetom Verio, Siemens, Germany). 3 healthy volunteers participated in this study after giving informed consent. Short-term ischemia and reactive hyperemia were provoked by a cuff-compression paradigm. A conventional leg sphygmomanometer was fixed at mid-thigh level. Cuff compression with a pressure of 50 mm Hg above the individual brachial systolic blood pressure was applied during the ischemic phase for 5 minutes. Cuff compression was performed manually within 10 seconds. Data acquisition started 3 minutes prior cuff compression (first minute used for reference scan and dummy scans) and ended 10 minutes after reperfusion. Parameters of the PRESS sequence were: TR=3000ms, TE=28ms, TI=1500ms, voxel size: 18x18x6mm<sup>3</sup>, bandwidth: 1000Hz. To assure complete inversion of the voxel, a 12mm slice was inverted in case of the selective inversion experiment. Magnitude spectra were used for quantification, the difference between tag and control scans was calculated and integrated over 500 Hz, centered on the water line. For normalization, a reference scan (without inversion) was treated the same way and the area under the line of the difference signals was divided by that of the reference signal. 5 consecutive acquisitions with non-selective (control experiment) or slice-selective inversion (tag experiment) were averaged resulting in a temporal resolution of the perfusion measurement of 30s. Perfusion was then quantified using

$$f = \lambda \frac{\Delta M}{M_0} \frac{e^{-TI/T_1'}}{1/T_a} (\alpha' + 1) (e^{TI/T_a} - e^{\Delta t/T_a})$$

with the following parameters and used constants:

$\Delta M$  = measured and normalized signal difference between tag and control scan

$\lambda = 0.9$  ml/g: tissue/blood partition coefficient of water

$\Delta t = 0.1$  s : transit delay after which first tagged blood arrives in the observed voxel

$\alpha' = -M_{\text{after inversion}} / M_{\text{before inversion}} = 0.9$  : degree of inversion

$T_1' = 1420$ ms : apparent longitudinal relaxation time in the presence of perfusion ( $1/T_1' = 1/T_{1,\text{tissue}} + f/\lambda$ )

$1/T_a = 1/T_1' - 1/T_{1,\text{blood}}$

TI = 1500ms : Inversion delay

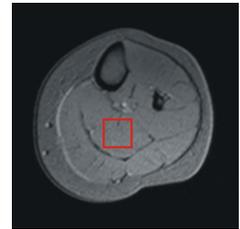


Fig. 1: Location of the PRESS voxel in the soleus muscle of one volunteer.

**Results.** Fig. 2 shows the measured signal intensities in arbitrary units of one subject averaged over 5 tag (green) and control scans (blue). The ischemic phase is shaded in gray. The corresponding temporal evolution of the muscle perfusion is plotted in Fig. 3. Averaged over three subjects, a mean resting state perfusion of 24 +/- 7 ml/100g/min and a mean maximum perfusion during hyperemia of 139 +/- 32 ml/100g/min were found.

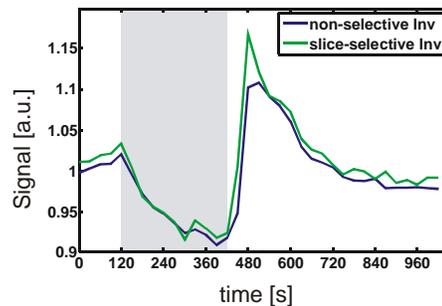


Fig. 2: Acquired signal in m. soleus (5 averages/temporal resolution 30s) after non-selective (blue) and slice-selective (green) inversion of one subject during short term ischemia/reactive hyperemia paradigm.

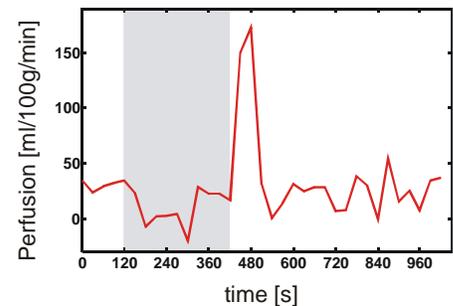


Fig. 3: Perfusion of m. soleus during short term ischemia/reactive hyperemia paradigm calculated from data presented in Fig. 2.

**Discussion.** The presented single-voxel FAIR technique results in quantitative perfusion values that are in good agreement with literature data. The achieved temporal resolution was sufficient to follow perfusion changes during the applied hyperemia paradigm. In conclusion, single-voxel FAIR seems to be a good candidate for quantitative perfusion measurements in skeletal muscle.

## References

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4. Pohmann et al. Fast Perfusion Measurements in Rat Skeletal Muscle at Rest and During Exercise with Single-Voxel FAIR. *MRM* 55:108,2006.