

Dynamic BOLD MRI of calf and foot muscles

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Introduction

Blood oxygenation level-dependent (BOLD) magnetic resonance imaging (MRI) is based on local changes in oxyhemoglobin and deoxyhemoglobin concentrations. BOLD MRI allows a non-invasive assessment of tissue oxygenation. It has been shown that dynamic BOLD imaging of the calf muscles during a short term ischemia / reactive hyperemia paradigm provides qualitative information on vascular function in patients with peripheral vascular disease (1). Aim of this study was to evaluate the feasibility of simultaneous MR BOLD imaging in calf and foot muscles in order to enable the examination of blood supply of most peripheral tissues.

Material and Methods

15 healthy volunteers participated in this study. The experimental protocol was approved by the local ethics committee. MR experiments were performed at 1.5 Tesla on a Siemens Avanto system (Siemens Medical, Erlangen, Germany). 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 3 minutes. Cuff compression was performed manually within 5 seconds. Subjects were lying in supine position for at least 15 minutes prior to the compression paradigm. The BOLD signal was measured by T_2^* quantification using a segmented multi-echo EPI sequence with $\alpha=25^\circ$, TR=92ms, TE=7.6, 17.7, 27.8, 37.9ms. Fig. 1 shows the approximate location of the two acquired slices. Temporal resolution was 1 second. The short term ischemia / reactive hyperemia protocol was applied consecutively to both legs of each subject. Reactive hyperemia was characterized by three parameters: the initial slope (IS) of the T_2^* change after opening the cuff, the time span from opening the cuff to maximum BOLD signal change (TTP) and the relative T_2^* change from end of ischemia to T_2^* at TTP (deltaS).

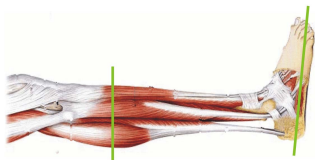


Fig. 1: Slice positions for interleaved BOLD imaging in calf and foot

Tab. 1: Initial slope IS (first 10 seconds), time-to-peak (TTP) and relative signal change during reactive hyperemia averaged over both legs of all subjects.

	Calf	Foot
IS [ms/10s]	1.8	0.4
TTP [s]	36	68
deltaS [%]	15.6	8.0

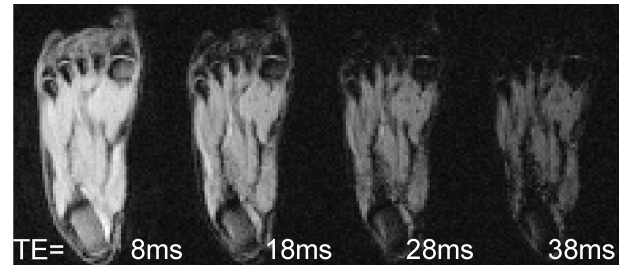


Fig. 2: Individual echo images acquired with a segmented multi-echo EPI sequence that were used for calculation of T_2^* maps of the foot muscles.

Results

Spatial resolution of the acquired image data was 2.3x2.3x6mm³ and allowed exclusion of large vessels from further analysis. Fig. 2 shows a typical example of the 4 acquired echo images used for T_2^* quantification in the foot muscles. The temporal evolution of T_2^* in m. soleus of the calf and m. adductor hallucis of the foot during the cuff compression experiment is displayed in Fig. 3. The reactive hyperemia led to higher and faster T_2^* changes in m. soleus than in the foot muscle. Numerical values that describe the observed T_2^* changes are given in table 1.

Discussion

For the investigation of vascular disorders spin-labeling perfusion techniques appear to be the method of choice [2]. However, their inherent low signal-to-noise ratios together with the low resting state skeletal muscle perfusion complicate their application to e.g. ischemia / reactive hyperemia experiments that can be employed to examine vascular malfunctions. This study demonstrates the feasibility of simultaneous BOLD measurements in calf and foot muscles. Further studies have to clarify, if disorders in the peripheral vascular system cause significant changes of the T_2^* evolution in foot muscles during a cuff compression paradigm.

Reference

- Ledermann HP et al. Blood oxygenation level-dependent magnetic resonance imaging of the skeletal muscle in patients with peripheral arterial occlusive disease. Circulation 2006;113:2929.
- Carlier PG et al. Muscle blood flow and oxygenation measured by NMR imaging and spectroscopy. NMR Biomed. 2006;19:954.

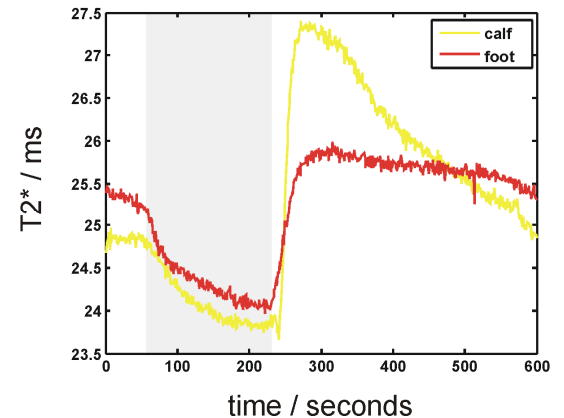


Fig. 3: Evolution of T_2^* in m. soleus (calf, yellow) and m. adductor hallucis (foot, red) during an ischemia / reactive hyperemia experiment averaged over both legs of all subjects. The ischemic phase is shaded in gray.