Dynamic analysis of T_2 and proton density of exercise-induced muscle using SE-EPI

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Target audience Researchers in MR physics and muscle physiology

Purpose Understanding of exercised muscle activity has been one of the hot issues in sports medicine and rehabilitation medicine. Although MRI is a useful technique to obtain quantitative values of relaxation times and proton density, most of the previous MRI studies of exercised muscle activity discussed changes of MR signal [1 - 5]. Changes of T_2 in the exercised muscle are speculated based upon the results of the near-infrared spectroscopy measurements, and various physiological mechanisms are proposed. However, physiological understanding of exercised muscle activity is still controversial. In this study, we first tried to obtain dynamic changes of T_2 and proton density quantitatively after the muscle exercise.

Materials and Methods The right calf of four subjects (20.5±1.7 years, 174.8±8.7 cm, 59.0±2.7 kg) was imaged on a clinical 1.5-T whole-body MR scanner (Magnetom Symphony, Siemens AG, Germany) with an extremity coil. To observe the difference of T_2 decay between single echo and multiple echo pulse sequences in resting muscle, we performed spin-echo echo planar imaging (SE-EPI) as a single echo pulse sequence and multiple spin echo (MSE). Fifteen TEs (30, 45, 60, …, 240 ms) were employed with TR 2000 ms, matrix 256×256, FOV 240×240 mm, slice thickness 10mm, NEX 1. To obtain the dynamic changes of T_2 and proton density after the performance of 200 times of ankle planter flexion using a training-gum-belt (Thera-Band, U.S.A), a set of four SE-EPIs was performed by changing TE (30, 45, 60, 75 ms) successively with TR 2000 ms and this set was repeated every 30 s immediately after the exercise. On the obtained images, an ROI was placed in tibialis anterior (TA) muscle and signal intensity was measured. The dynamic changes of the transverse relaxation rate (R_2) and the proton density (Mo) were calculated using mono-exponential regression analysis.

Results and Discussion Figure 1 shows the T_2 relaxation curves of TA obtained by MSE and SE-EPI. Although signal intensities of SE-EPI decreased rapidly due to the influence of tissue magnetic inhomogeneity and diffusion of water, signal intensities of both MSE and SE-EPI were not deviate in short TEs (≤ 75 ms). Therefore, signal intensities of SE-EPI with these TEs are free from the above influence as well as MSE for the R_2 measurement. Figure 2 shows MR images of the right calf at resting state and after the exercise. As TA works predominantly during ankle planter flexion, the signal intensity of TA increased after the exercise. Time courses of R_2 and M_0 after the exercise are shown in Fig. 3. Both values of R_2 and M_0 peaked at 1 minute later of after the exercise minimally and maximally, respectively. As the data at 30 s in Fig. 3 is the data obtained just after the exercise, both R_2 and M_0 greatly change during the 30 s and this first data are not reliable; we discuss the data excluding these data. The decrease of M_0 reflects that the swelled blood volume during the exercise is decreasing to the resting state blood volume after the exercise in about 4 minutes (Fig. 3b). The exponentially-extrapolated value of M_0 (1341) indicates the excessive increase in blood volume is 13% of the proton density of resting state, agreeing within the range of the previous studies by using other methods like plethysmography. The excessive blood volume after the exercise gives rise to larger blood flow than at resting state, and larger blood flow increases blood oxygenation; this explains the decrease of R_2 values from the resting state value (Fig. 3a). Using the oxygenation dependency of R_2 of the blood [3], the increase of blood oxygenation does not fully explain the decrease of R_2 (-7.9) at 1 minute after the exercise. The slight change of the R_2 recovery process appears at 4 minute after the exercise (Fig. 3a) as well as changes in M_0 (Fig. 3b) indicating the existence of two components with different relaxation times. The fast relaxation component of R_2 appearing until 4 minute would be ascribed to the venous blood. Although the origin of the slow relaxation component of R_2 is unknown, the existence of this component suggests the structural changes of water in muscle fibers.

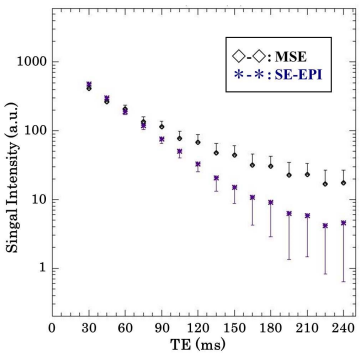

Figure 1: Signal intensity of tibialis anterior muscle versus TE at resting state.

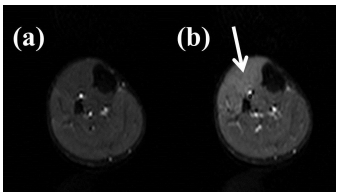

Figure 2: SE-EPI images in lower leg at rest (a) and immediately after the exercise (b). Tibialis anterior muscle is predominantly activated (arrow).

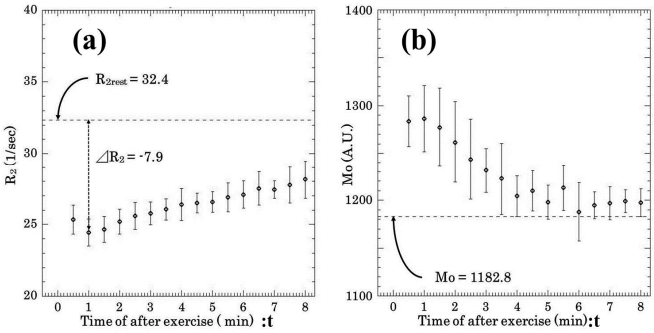

Figure 3: Time course of R_2 (a) and Mo (b) of tibialis anterior muscle after the ankle planter flexion exercise. The values at resting state are indicated as R_{2rest} and M_{0rest} (dashed lines).

Conclusion Using SE-EPI, temporal resolution of dynamic study of exercise-induced muscle can be shortened to 30 s and dynamic changes of R_2 and M_0 were quantitatively obtained for the new understanding of exercised muscle activity.

References

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