Skeletal muscle pH time course predicts water T2* during repeated exercise

Albrecht Ingo Schmid[1,2], Kiril Schewzow[1,2], Sigrun Goluch[1,2], Georg Fiedler[1,2], Fabian Niess[1,2], Elmar Laistler[1,2], Michael Wolzt[3], Ewald Moser[1,2], and Martin Meyerspeer[1,2]

[1]Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Vienna, Austria, [2]MR Centre of Excellence, Medical University of Vienna, Vienna, Austria, [3]Department of Clinical Pharmacology, Medical University of Vienna, Vienna, Vienna, Austria

Introduction

^{31}P MRS is known to measure cellular energy metabolism and pH. Skeletal muscle functional magnetic resonance imaging (mfMRI), measuring T_2^* contrast, has been used frequently in recent years to study effects of exercise, ischemia or both in healthy volunteers or patients.

Methods

20 data sets of young healthy subjects of combined ^{31}P MRS and mfMRI before, during, and after 5 min. plantar flexions at approximately 30 % maximum voluntary contraction force were acquired on a 7 T MR scanner (Siemens, Germany) using a custom-built ^{31}P/^{1}H calf coil array [1].

^{31}P spectra were acquired within gastrocnemius muscle using accurate semi-LASER [2] localisation (voxel size ~ 36 ml, T_E = 24 ms). Axial EPI were acquired (FOV = 16 cm, T_E = 20 ms). T_R was 6 s, during which volunteers did repeated plantar flexions for 5 min.

The ^{1}H EPI signal (S_{EPI}) in ROI (gastrocnemius medialis) was integrated and normalised. pH was determined from P_i and PCr resonances, quantified using jMRUI/AMARES. A linear model analysis was used on the EPI signal and pH during exercise: $S_{EPI} = a * pH + b$.

Results

During exercise, pH increased from resting values to 7.11±0.02 and dropped to end-exercise values of 6.75±0.23. EPI signals on the other hand, first dropped to 0.94±0.06 and then increased to 1.09±0.10. pH was found to predict EPI signals very well during exercise and at the beginning of recovery R^2=0.72±0.16.

As can be seen from Figure 2, parameters *a* and *b* are stable for all subjects, or there was no significant pH change.

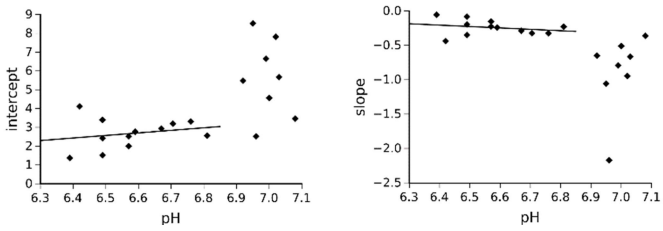

Figure 2 Slope and intercept as function of end-exercise pH. When significant pH changes occur, both slope and intercept are approximately constant. When pH does not show big alterations, any combination will give similar results.

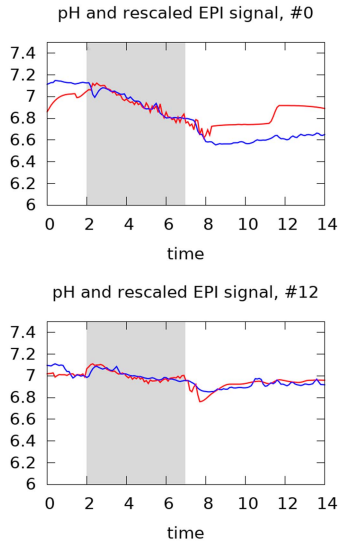

Figure 1 pH time course and rescaled EPI signal in a volunteer with moderate (top) and little (bottom) acidification. Note the excellent agreement during exercise even though the data was recorded in repeated exercises (min 2 – 7) with an ~30 min interval.

Conclusion

During exercise, T_2^* is correlated to intracellular pH, confirming previous findings [3]. The underlying process is most probably proton-dependent osmotic water shift [3]. Contrary to what was reported, the present results obtained with high spatial and temporal resolution indicate simultaneous changes of T_2^* and pH. T_2^* changes before and after exercise cannot be explained by pH alone, volume changes [4], other osmotic effects or the BOLD effect may contribute significantly.

References:

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