Perfusion measurement in the exercising rat leg muscle with single-voxel fast FAIR

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Introduction:
Arterial spin labelling has become a commonly used tool for measuring the perfusion in the brain and other highly perfused organs. In skeletal muscle, the perfusion is much lower and not within reach of most measuring methods due to their insufficient sensitivity [1]. A quantitative measurement for muscle perfusion would be highly valuable for medical and pharmaceutical research for peripheral artery occlusion disease (PAOD). We have implemented a method to measure the perfusion in the rat leg muscle at rest and exercise with precision and good temporal resolution.

Technique:
We have modified the FAIR technique [2] to measure the perfusion in the hindlimbs of rats. To cope with the low SNR due to the very low perfusion in the skeletal muscle, the sequence was optimized for maximum sensitivity:
A single-voxel PRESS sequence (voxel size 6×6×3 mm) was used rather than an imaging readout with high spatial resolution [3]. The sequence timing was adapted to obtain maximum sensitivity and a good temporal resolution.

Experimental:
Measurements were performed on a 4.7 T Biospec. The rats were aneasthetised with isoflurane and N_2O. To measure the perfusion during exercise, the hind limb was placed in a home-built leg-holder with which it was possible to electrically stimulate the gastrocnemius muscle and to measure the force with which the muscle reacted. With 16 averages, a temporal resolution of 2.3 min was obtained.

Results:
Fig. 1 and 2 show the time evolution of the measured perfusion at rest and during exercise. In Figure 1, the muscle had to work twice for about 22 minutes with a resting period of 15 minutes, the second stimulation period with a higher work load than the first. In figure 2, stimulation periods of 5 minutes were followed by resting periods of 10 minutes, the workload being increased for every period. The perfusion at rest was about 22 ml/100g/min, with a two- to threefold increase during exercise. In an additional experiment, five rats underwent a similar stimulation protocol twice. The first time, the perfusion was measured with NMR, the second time with microsphere injections before, immediately after and some minutes after exercise, showing a close agreement of both techniques.

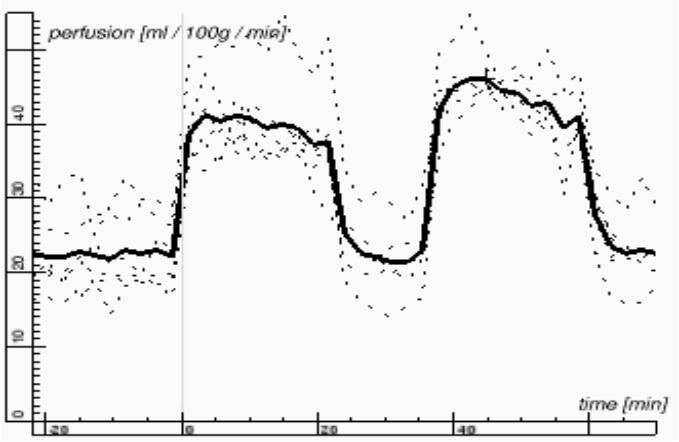

Fig. 1: Perfusion at rest and under two levels of exercise, measured in six rats. Dotted lines: individual animals, straight line: mean.

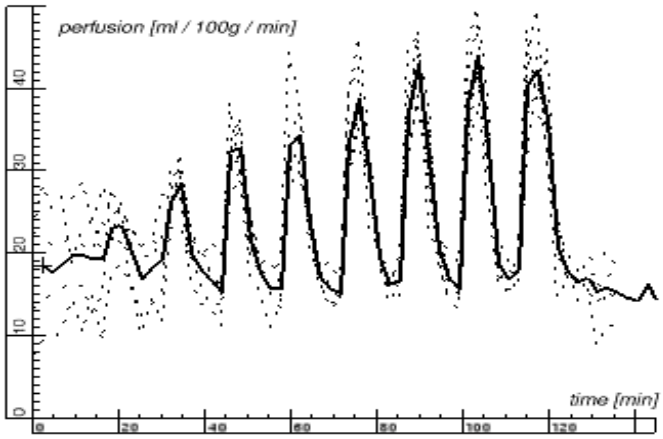

Fig. 2: Perfusion for eight different levels of exercise in five rats.

Conclusion:
By restricting our measurements to a single voxel and optimizing the timing, we were able to measure the perfusion in the skeletal rat muscle at rest and during exercise with a good precision and temporal resolution.

References:
[1] Bertoldi et al., ESMRMB 2003, Presentation 304
[2] Kim, MRM **34**, 293 (1995)
[3] Marro, Kushmerik, MRM **38**, 40 (1997)