Measurement of skeletal muscle perfusion at rest and its change after exercise using Arterial Spin-Labelling

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Introduction

Perfusion is an important parameter in the assessment of disease or dysfunction in various tissues. In particular, pathological changes of skeletal muscle perfusion can be found in various muscular diseases, such as degenerative or inflammatory myopathies. Since sole assessment of muscle morphology often only reveals non-disease-specific results, perfusion MR-imaging by visualizing patho-physiologic changes of muscular microcirculation might increase disease specificity of MR-imaging. A non-invasive approach using Arterial Spin-Labelling (ASL) has been chosen in the present study, in order to monitor perfusion in all skeletal muscles of the thigh [1] at rest and after defined exercise schemes. Exercise-induced hyper-perfusion is expected to be observable in the strained muscle groups [2].

Materials and Methods

In this ongoing study, the perfusion in a 10 mm axial slice of the mid-thigh was imaged in 5 healthy volunteers (3 male, 2 female; median age, 25 years). The measurement was performed on a 1.5 T whole body scanner (MAGNETOM Avanto, Siemens Medical Solutions, Erlangen, Germany) using a dedicated extremity coil or a body matrix coil, depending on the positioning of the volunteer on the stretcher. The PICORE [3] tagging-scheme was implemented using FOCI pulses [4] for inversion in combination with fast HASTE readout (TR = 3500 ms, TE = 30 ms, 256x128 Matrix, Bandwidth = 500 Hz/Px) to acquire the tagged and the control image. Blood was tagged in a slab (80 mm thickness) slightly superior to the imaging slice (gap of 20 mm) and given an inflow time (TI = 600 ms) to enter the capillary bed. The examination protocol started with a pre-exercise ASL imaging block acquiring 25 tagged and 25 control images (TA = 3 min) to obtain a reference perfusion image. This was followed by a standardized defined exercise element. The subject had to exercise against a 3 kg weight that was attached to the lower leg for 5 min. Immediately thereafter, a second ASL image series with identical parameters was acquired.

Averaging was performed in a post-processing step separately for the tagged and the control images. The first two acquisitions of each series were discarded, because of errors due to initial transition towards a dynamic equilibrium state. This step was followed by subtraction of the two resulting datasets, in order to suppress static tissue.

Results

The presented method delivers reproducible perfusion data of skeletal muscles at rest (Fig. 1) and after defined exercise (Fig. 2). High resolution and high SNR allow for delineation of muscle groups and the separate, muscle specific assessment of local perfusion. ASL visualizes exercise-induced hyper-perfusion in individual muscles or muscle groups (Fig. 2). Moreover, effects of different exercise schemes, i.e. exercising the extensor or flexor muscles, on muscle microcirculation can be assessed. After defined knee-extension exercise, the median increase in perfusion was 25% - 35% within the quadriceps muscle and after defined knee-flexion exercise, the median increase in perfusion was up to 80% within the thigh-flexor muscles.

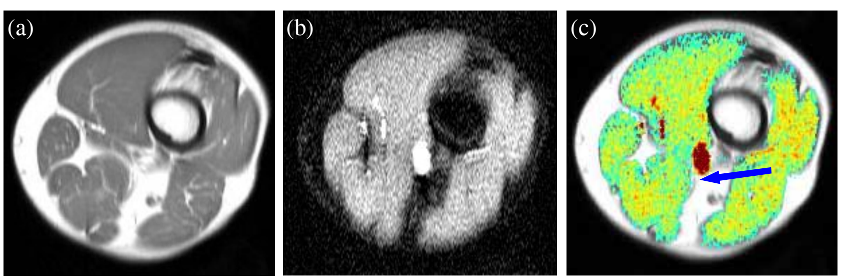

Figure 1
Images from the left mid-thigh of a 27-year-old man after 30 minutes of rest on a stretcher.
(a) Anatomic T_1 weighted image of the slice of interest
(b) ASL perfusion-weighted image
(c) Colour-coded perfusion-weighted image
The blue arrow indicates the femoral vessels.

Discussion and Conclusion

ASL MRI allows for reproducible visualization of skeletal muscle perfusion and therefore may be a promising functional imaging method for various myopathies, such as inflammatory myopathies, where muscular microcirculation should be elevated. In sports medicine, training effects on individual muscles could be monitored, which may improve training schemes. Absolute quantification of skeletal muscle perfusion would be desirable and might also be implemented for skeletal muscles, e.g. using the introduced sequence together with the Q2TIPS method [5].

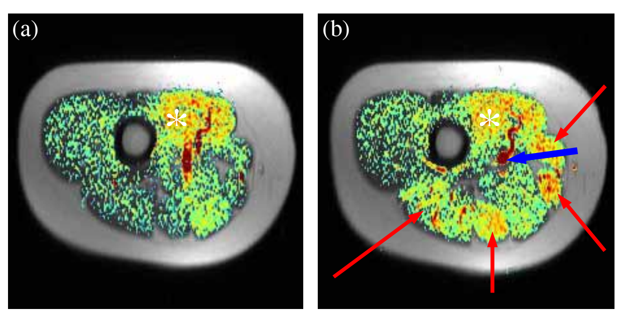

Figure 2
Colour-maps showing relative perfusion in a slice of the right mid-thigh of a 24-year-old woman (a) before and (b) after knee-flexion exercise. Significant hyper-perfusion in all thigh-flexor muscles can be observed (arrows), while the adductor muscles (asterisk) already have elevated perfusion at rest. The blue arrow indicates the femoral vessels.

References

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