Spin-Labeling Muscle Perfusion Imaging at 3 Tesla

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Purpose:

Reduced tissue perfusion of skeletal muscle is a common symptom in many chronic diseases such as diabetes mellitus type II or systemic rheumatic diseases. Early diagnosis may reduce the risk of severe complications. In this study, a pulsed arterial spin labeling (pASL) approach was used to obtain quantitative perfusion maps of the skeletal muscle in a clinical 3 Tesla whole-body scanner. The aim of this study was to test and demonstrate the feasibility of quantitative ASL muscle perfusion imaging in diagnostic imaging quality using a clinical MR set-up.

Materials and Methods:

Eight healthy volunteers aged between 24 and 42 years (mean age 32) participated in this study. A pASL sequence with flow-sensitive alternating inversion recovery (FAIR) [1-2] spin preparation and true fast imaging in steady precession (TrueFISP) signal readout strategy was implemented in a clinical 3 Tesla MR scanner. The TrueFISP image acquisition technique was chosen because this method is less sensitive to magnetic field inhomogeneities as compared to echo-planar imaging. Quantitative perfusion maps were obtained on a pixel-by-pixel basis using a simplified perfusion model derived from the extended Bloch equations [3]. Perfusion maps were acquired before and after intensive exercise of the forearm musculature. The obtained perfusion curves were correlated to T1-, T2-relaxation and proton-density measurements. Additional correlation was performed to arterial and venous blood flow measurements using phase-contrast imaging.

Results:

The perfusion maps with an in-plane resolution of 1 mm showed no significant distortions or blurring artefacts. Perfusion-time curves could be recorded with a temporal resolution of 6.4 sec. The perfusion of the musculature reached a maximum approximately 2 minutes after exercise with perfusion values of up to 220 ml/min/100g tissue showing good delineation between active muscles and non-active muscles (Fig. 1 and 2). The signal curves of slice selective and global inversion declined to a lower signal level after exercise, which reached a minimum approximately 5 minutes after exercise and a subsequent prolonged recovery to the basal signal intensity (Fig. 3). This reduction in signal intensity was shown to be due to longer lasting changes of T1, T2 and proton density of the muscle after exercise. The perfusion changes after exercise showed a higher correlation to the venous blood flow ($R = 0.98$) than to the arterial blood flow ($R = 0.96$).

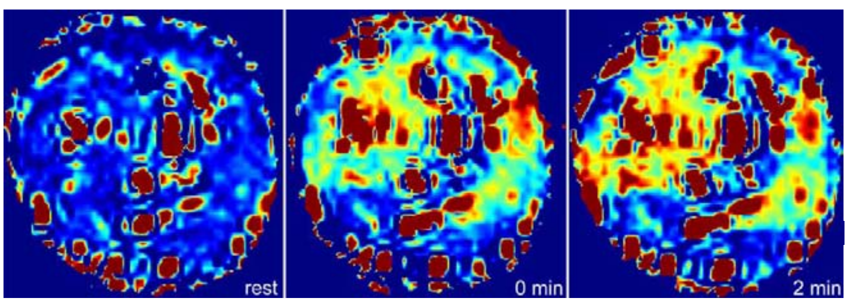

Fig. 1: Quantitative perfusion images (average of 10 images) at rest, and at different times after intense exercise. The highest perfusion rates were found in the flexor muscle group consisting of the flexor digitorum profundus and sublimis muscle, and in some extensor muscles.

Conclusion: The TrueFISP pASL technique allows for patient-friendly assessment of muscle perfusion with high temporal resolution and good image quality using a clinical 3.0 Tesla MR set-up. This technique may be used for further studies investigating reduced muscle perfusion in chronic illnesses.

References:

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[3] Calamante F, Thomas DL, Pell GS, et al.. J Cereb Blood Flow Metab. 1999;19:701-35.

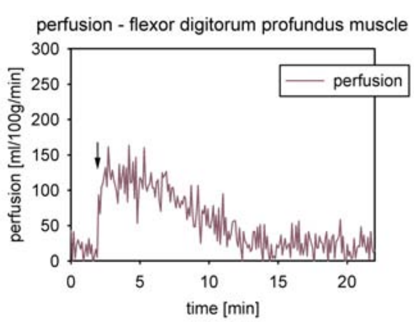

Fig. 2: The flexor digitorum profundus muscle shows a fast increase of the perfusion rate after the exercise, which reaches a peak 2 minutes after exercise and declines within 10-12 minutes to the basal perfusion rate.

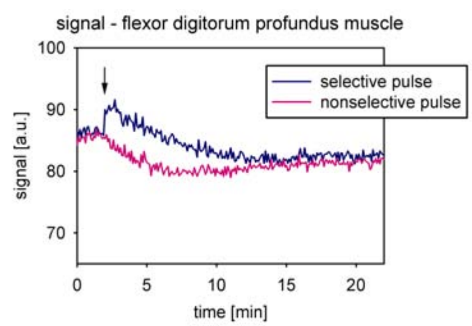

Fig. 3: The difference between the two signal curves is proportional to the tissue perfusion. Both signal curves exhibit a more prolonged decline than the perfusion curve.

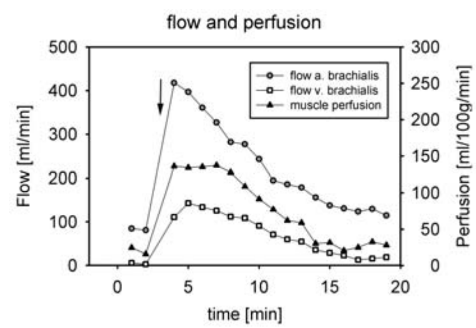

Fig. 4: Blood flow within the brachial artery ($R = 0.96$) and the brachial vein ($R = 0.98$) measured by MR phase contrast imaging was correlated to the perfusion curve.