Calf Muscle Perfusion Measurement by Rapid Time-Resolved Spiral FAIR-ASL

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Introduction

Peripheral Arterial Disease (PAD) is a disease characterized by reduced flow of blood to lower extremities due to atherosclerosis in vessels supplying blood. Therefore it is clinically valuable to be able to assess blood flow in PAD patients as well as monitor therapeutic interventions non-invasively. Here a novel skeletal muscle perfusion measurement technique is introduced by combining Flow-Sensitive Alternating Inversion Recovery (FAIR), a pulsed arterial spin labeling (ASL) method, for inflow labeling and spectral-spatial excitation with spiral for readout. FAIR labeling is achieved by alternating selective and non-selective inversion pulses to get MR images that are used as tag and control respectively. By subtracting the control images from the tagged image, it is possible to get perfusion-weighted images from which localized spatial and temporal perfusion measurements can be determined. In our study, calf muscle perfusion was measured by inducing ischemia due to exercise and perfusion heterogeneity of different calf muscle groups was examined. Artifacts and contamination from large blood vessels can be a problem with this technique and in order to reduce this undesired intravascular enhancement, the extent of labeling was limited by modifying the conventionally non-selective inversion to be slightly selective [1]. Diffusion preparation was also implemented just before readout excitation in order to suppress the majority of the intravascular signal [2].

Methods

We implemented time resolved high resolution spiral ASL pulse sequence by using hyperbolic secant inversion pulses for both tag and control FAIR labeling and spiral readout after spectral-spatial excitation. We used two 16.4ms spiral interleaves. In order to reduce contamination of perfusion signal by large vessels, diffusion weighted preparation was used just before the spectral-spatial excitation. Diffusion preparation was achieved by a pair of diffusion sensitizing gradients placed before and after the 180 pulse of a 90-180-90 train of hard pulses with a total of 10ms duration. In vivo images of volunteers were acquired with a 1.5T Siemens Avanto whole body scanner using before and after exercising to exhaustion on a planter-flexion exercise ergo-meter affixed to the MR patient table. The imaging parameters included slice thickness of 8mm, FOV of 20cm, TI of 624ms and TR of 2s. The slice selective inversion had a thickness of 16mm whereas the slightly selective inversion had a thickness of 150mm. Images with the same slice thickness but without diffusion preparation as well as with diffusion preparation of sensitizing gradient strength of 14mT/m and 28mT/m were acquired.

Results and Discussion

Figure 1 shows perfusion images using the pulse sequence we implemented with different degrees of intravascular signal suppression. Figure 1a shows significant intravascular signal contamination is still present even if the non-selective slice was modified to be a slightly selective slice with width of 150mm. In Fig. 1b, the intravascular signal has been moderately suppressed by the diffusion preparation with gradient strength of 14mT/m but the perfusion signal has been also significantly reduced. 1c shows that the intravascular signal has been suppressed for the most part.

In Fig. 2, average intensity values of the subtraction images of different muscle groups in calf muscle are plotted before and after exercise from ROI chosen to avoid vasculature and contaminated areas. The intensity levels of all muscle groups in Fig. 2a are higher than in 2b and 2c since diffusion preparation was not used. The increase in intensity in the tibialis anterior was observed in all of the plots post exercise up to about 30%, although the increase seems to persist for a longer time in the images where maximum diffusion sensitizing gradients were used. The slight perfusion increase observed in the soleus area post exercise returned to the baseline in all of the images collected. The intensity of the medial gastrocnemius area, however, decreased with increased diffusion sensitizing gradient strength post exercise.

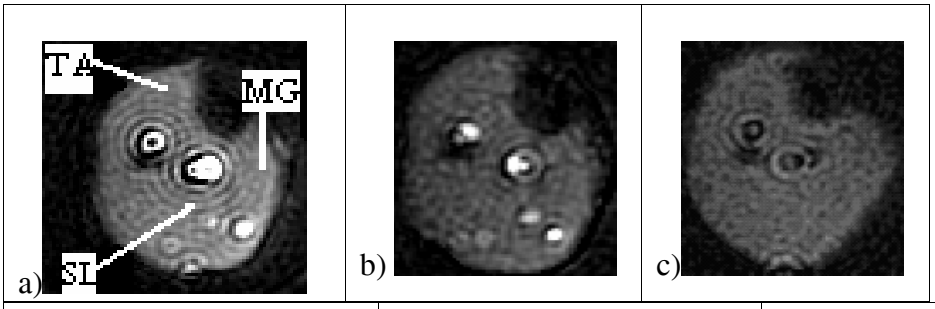

Figure 1. Images with slightly selective inversion of 150mm (instead of the conventional non-selective inversion) with diffusion preparation of different sensitizing gradients, 0mT/m(a); 14mT/m(b); 28mT/m(c). TA-Tibialis Anterior, SL-Soleus and MG-Medial Gastrocnemius.

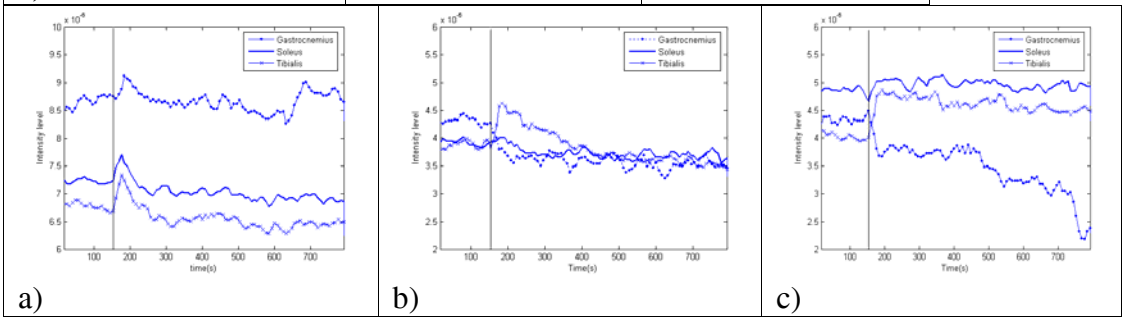

Figure 2. Perfusion intensities of ROI in different muscle groups, pre and post exercise, as a function of time with different sensitizing gradients, 0mT/m(a); 14mT/m(b); 28mT/m(c).

Conclusion

We have demonstrated that a time resolved spiral FAIR ASL sequence has potential in the measurement of skeletal muscle perfusion. In addition, we have shown that suppression of intravascular signal can be achieved by modifying the conventionally non-selective slice in combination with implementing diffusion preparation. Even though the increased perfusion in the tibialis after exercise was consistently shown in the images taken, the heterogeneity of responses by different muscle groups requires further investigation.

References

1. Zhang Y, et al. JMRI 2005, 22:119-124, **2**. Pell GS, et al MRM 2003, 49:341-350, **3**. Boss A, et al NMR Biomed 2006, 19:125-132