Continuous arterial spin labeling in progressive peripheral vascular disease

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Introduction

Measurement of muscle perfusion in the extremities is feasible using arterial spin labeling (ASL) MRI (1-3) and may provide means for investigating of regional microvascular flow in normal muscle as well as in disease states. In non-diseased skeletal muscle, it has been noted that the blood supply after exercise and hyperemia is not uniform across muscle groups (4,5). On the other hand, pathological variability in flow within individual muscle groups may exist in states of small vessel disease (e.g., diabetes mellitus), peripheral vascular disease (PVD) and other muscle diseases. In this study, we utilize continuous ASL (CASL) to measure the perfusion in patients with PVD. Flow variability is analyzed for individual muscle groups and correlated to the disease severity assessed by the ankle to brachial index (ABI), a standard clinical measurement that compares blood pressures in the distal lower and proximal upper extremities.

Materials and Methods

With IRB approval and appropriate consent obtained, 38 subjects underwent measurement of ABI and CASL imaging at the level of the mid-calf. Studies were conducted on a 3.0 T Siemens Trio whole-body MR system with a transmit/receive knee coil. A tourniquet system with nonmagnetic cuff placed on the thigh and inflated to 250 mmHg to create a 5-min period of ischemia followed by a period of hyperemic flow. CASL imaging started in synchrony with cuff occlusion and continued for 3 min after cuff deflation. A single-slice version of CASL sequence optimized for 3.0 T was used (6). The labeling plane was 6 cm proximal to the target slice (1 cm, axial) for the tag images and 6 cm distal for the control. Other imaging parameters were as follows: TR = 4 sec, TE = 17 msec, FOV = 22 cm, in-plane matrix size = 64x64, labeling duration = 2 sec, post-labeling delay = 1.9 sec. Complex data were constructed to magnitude images and then exported to a workstation for post-processing. Data analysis was conducted with VOXBO (http://www.voxbo.org/) and homemade scripts programmed with IDL (RSI, Boulder, CO). ASL signals were generated by pair-wise subtraction and then converted to absolute flow in a unit of ml/100g/min following the model in Ref (1), assuming T1 = 1.5 sec, T2* = 80 ms for blood and T1 = 1.2 sec, T2* = 20 ms for tissue at 3.0 T. Regions of interest (ROI's) were manually determined on a high resolution 2D spoiled gradient-echo anatomic image that matched the location where CASL images were obtained. Three muscle groups in the mid-calf were analyzed: Anterior Extensor (AC), Gastrocnemius Medial Head (GMH) and Soleus (Sol). Multiple regression analysis was adopted to test the correlation between the dependent variable 'peak flow' and the covariates, 'muscle group' and 'disease severity' (assessed by ABI; see Table 1).

Results and Discussion

The cohort peak hyperemic flow is summarized in Table 1. Overall, the magnitude of flow response decreases with disease severity and the drop occurs earlier in AC (starting from category 2) than in the other two muscles inspected. Although the peak flow seems relatively unchanged in GMH and Sol between category 0 and category 2, the flow-time curves as shown in Fig 1 are found to have a delayed peaking time and a broader shape as the severity increases. At category 3, the hyperemic flow pattern begins to markedly deteriorate in all muscle groups.

Conclusion

CASL flow measurements correlate with disease state as measured by ABI, but also demonstrate a retained microvascular flow reserve in the presence of early to intermediate vascular disease (category 0-2). Progression of disease is followed by diminished flow reserve and delayed hyperemic response.

Table 1. Peak hyperemic flow averaged across subjects (ml/100g/min)

ABI	Category	n	AC	GMH	Sol
0.9≦ ≦1.3	0	10	75±27	72±44	86±45
0.7≦ < 0.9	1	10	90±55	69±29	102±50
0.4≦ < 0.7	2	14	60±21	66±33	101±63
< 0.4	3	4	35±5	49±26	55±9

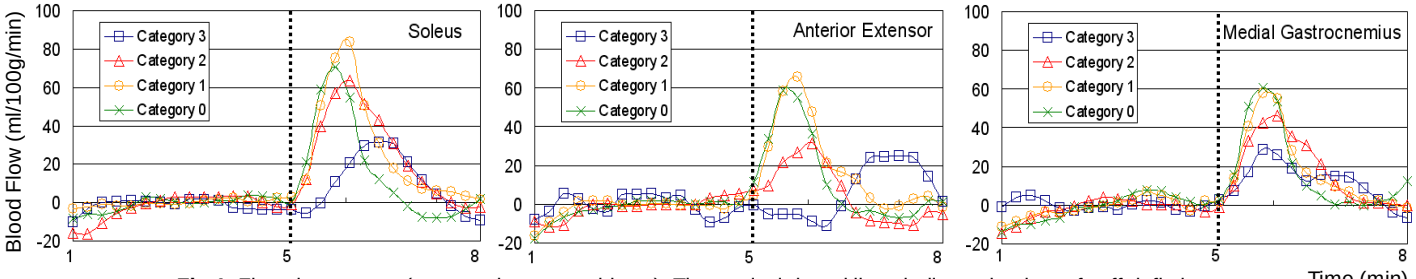

Fig 1. Flow-time curves (averaged across subjects). The vertical dotted lines indicate the time of cuff deflation.

References

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