Feasibility of the Application of CASL for the Diagnosis of Peripheral Vascular Disease

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Introduction: Measurement of muscle(calf) tissue perfusion has been achieved utilizing Continuous Arterial Spin Labeling(CASL)(2, 3). This approach may offer new and important insight for physicians in the management of patients with peripheral vascular disease(PVD). PVD appears to spare the vascular supply to the upper extremity, and the most commonly used tool to screen for PVD compares systolic pressure in the lower extremity with that in the brachial artery, the arm-brachial and toe-brachial systolic ratios. Standardizing CASL measured tissue flow in the lower extremity to that in the upper extremity may also have diagnostic value. CASL measurements may suffer from the effect of transit delay, and Alsop(1) has demonstrated that transit artifacts may be ameliorated via use of a delay period after labeling to allow labeled spins to exit the large vessels and enter the microvasculature. Subjects with PVD may have severely prolonged transit delay. In this study we attempt to estimate the optimum CASL-post labeling delays(PLD's) in healthy subjects anatomically relevant muscle groups in preparation for the application of this technique to subjects with PVD.

Methods: With IRB approval and appropriate consent obtained, 20 healthy subjects underwent a total of 90 imaging studies of the calf, foot, and forearm at varying PLD's. Due to the discomfort of the tourniquet, individuals were only able to contribute 3-4 sets of images in each session. Studies were conducted on a 3.0 Tesla Siemens Trio whole-body MR system. A custom designed dual-tuned proton/phosphorous transmit-receive knee coil (Nova Medical, Inc., Wakefield, MA) was utilized. A single-slice version the CASL sequence, optimized for 3.0T was utilized(4). The labeling plane was 6 cm proximal to the imaged 1cm slice(axial), FOV -22cm, matrix-64 x 64 for calf and 128 x 128 for the foot/forearm. TE was 13ms and the duration of the tag was 2 sec. During the control state, the inversion plane was placed 6cm distal to the imaging slice. Post labeling delays(PLD) tested were 1000, 1500, and 1900 msec. TR = 4 sec. A tourniquet system with nonmagnetic cuff placed on the thigh or upper arm was utilized at 250 mm-Hg to create a 5 minute period of ischemia followed by a period of hyperemic flow. Imaging commenced 2 minutes prior to tourniquet inflation and ended 3 minutes after tourniquet release. A high resolution MPRAGE sequence was also obtained. Post-processing utilized the appropriate MPRAGE slices to hand draw a ROI in the soleus muscle of the calf, and flexor muscle groups of the forearm and foot. Calculation of flow followed the model in reference (2), assuming blood T1=1.5s, blood T2*=80ms and tissue T1=1.2s, tissue T2*=20ms at 3.0T. Flow vs. time was plotted for each anatomic location at the varying PLD's. Peak flow was calculated for each anatomic region. Flow measurements were averaged between subjects.

Results: The CASL approach allowed for measurement of blood flow in the forearm, calf, and even the mid-foot during hyperemia. Representative flow-time course graphs for the forearm and foot are depicted below in Figures-1 and Figure-2 along with the anatomic and CASL images created from the hyperemic flow period. Each point represents the averaging of two labeled and two unlabeled images for smoothing. Peak flows obtained after release of the tourniquet are recorded in Table-1 for each anatomic location and PLD. In parentheses are recorded the peak flow ratios, calf/arm and foot/arm. The longest PLD of 1900 msec yielded the most robust flow data in each anatomic location. Recorded flows at each anatomic location increased with increasing PLD, however the peak flow ratios did not significantly increase over the range of PLD's tested.

Conclusions: CASL, even with a TR interval of 4 sec was able to adequately resolve the time course of the hyperemic flow pattern. Peak flows recorded in the calf were considerably larger than in the foot or forearm during hyperemia. The technique allowed visualization of robust flow patterns in all anatomic regions studied, especially at longer PLD's. It was not able to be determined at what PLD flow would plateau, probably due to prolonged transit time in muscle. Importantly however, even though peak measured flows increased with longer PLD's, flow, when referenced to forearm as a ratio, did not appreciably change. Thus, given the fact that flow in the forearm is preserved even in PVD, CASL , though potentially limited in its ability to document an absolute flow under certain circumstances, may allow accurate determination of the flow ratio. Although transit time in patients with PVD may be considerably compromised, given the robust flow detail documented in this study, it is reasonable to expect that lower flow states may be adequately documented by CASL to aide diagnosis. These preliminary studies provide a framework for the extension and further testing of the CASL approach as a noninvasive diagnostic tool to assist in the diagnosis of vascular disease.

Fig.-1

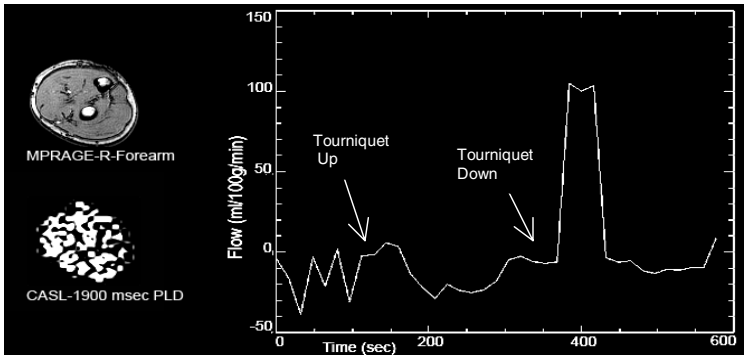

Fig.-2

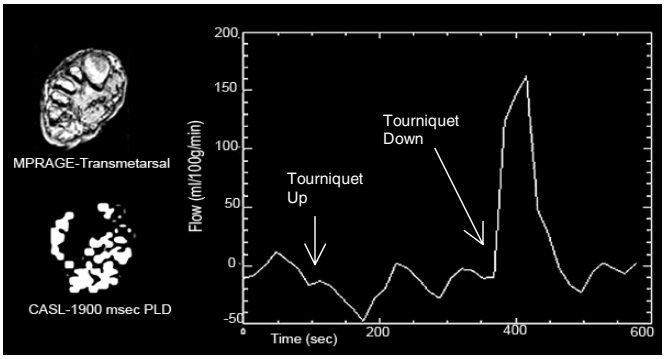

Table-1

Flow by Anatomic Region (ml/100g/min)	PLD-1000	PLD-1500	PLD-1900
Calf	85 ± 14 (2.1), N=14	143 ± 18 (2.7), N=8	173 ± 17(2.3), N=9
Foot	67 ± 10 (1.6), N=10	73 ± 12 (1.4), N=8	118 ± 9(1.6), N=13
Forearm	41 ± 7, N=12	53 ± 10 , N=6	76 ± 7, N=10

Bibliography

1. **Alsop DC and Detre JA.** Multisection cerebral blood flow MR imaging with continuous arterial spin labeling. *Radiology* 208: 410-416, 1998.
2. **Frank LR, et. al.** Dynamic imaging of perfusion in human skeletal muscle during exercise with arterial spin labeling. *Magn Reson Med* 42: 258-267., 1999.
3. **Lebon V, et al.** Simultaneous measurement of perfusion and oxygenation changes using a multiple gradient-echo sequence: application to human muscle study. *Magn Reson Imaging* 16: 721-729, 1998.
4. **Wang J, et. al.** Amplitude modulated continuous arterial spin labeling perfusion MRI with single coil at 3.0 Tesla. *Radiology (in press).*