Use of BOLD MRI for Objective Evaluation of Tissue Ischemia In Peripheral Vascular Disease

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Introduction:
Imaging of peripheral vascular disease (PVD) is currently limited to depiction of vascular anatomy. BOLD MRI has been used in the brain and kidneys to determine relative oxygen content. We propose using blood oxygen level dependent magnetic resonance imaging (BOLD MRI) in the lower extremities to assess the oxygen content in the calf muscles. The addition of such functional information in the assessment of PVD may enable a more objective primary assessment of limb ischemia and provide a way of monitoring outcome post intervention.

Material and Methods:
5 young adults (24–36 yrs; mean 32.2 yrs), 5 healthy age-controls (55-67 yrs; mean 62.2 yrs) and 3 patient with PVD (60-63 yrs; mean 61.7 yrs) were recruited and consented to participate in this IRB approved pilot study All participants answered a questionnaire on PVD risk factors.
BOLD MRI was performed on a 1.5T system (GE Healthcare, Waukesha, WI), using a torso phase-array coil (ICG-Medical Advances, Milwaukee, WI)). A multi-echo GRE sequence with 16 echoes at 1mm interval and 5mm slice thickness was used to obtain 2 slices through both calves at baseline (leg flat on the scanner table), 5 minutes after calf elevation (heel 17 cm above table), and after 2 minutes of dorsi- and plantar- flexion exercise in the scanner. (TR/TE/Flip/BW; 80/7-42/40°/62.5, FOV: 340 x 340 mm, matrix; 256 x 192, NEX 2.0) Each set of 16 T2*-weighted images requires 30 sec to obtain. The gray scale and color R2* map were generated and ROI were recorded in muscles of the calf bilateral, with an average of 6 ROI's per slice per leg. R2* values are expressed as mean +/-sd. The color maps were used to avoid placement of the ROI in an area of artifact and to visually look at the differences between subjects. Contrast-enhanced magnetic resonance angiography was performed on the three patients as part of their clinical work up. Statistical analysis was performed with Student's T Test.

Results:
The R2* values in the young adult volunteers and age-controlled volunteers showed no significant change between baseline R2* values in the calf, compared with elevation or elevation and exercise (Table 1). There were 3 diseased patients: Patient 1 had mild claudication (Rutherford, Grade I, Category I), and had 50% occlusion of her distal aorta, but no inflow or run-off disease. This patient showed no difference between baseline, elevation and elevation with exercise. Patient 2 had moderate claudication (Rutherford, Grade I, Category II), and had severe inflow disease at the right SFA with mild diffuse disease in 3 run-off vessels. This patient did not show any difference between baseline, elevation and elevation with exercise. Patient 3 had severe claudication (Rutherford, Grade I, Category III), and had diffuse inflow disease with occlusion of the right SFA and a 3 vessel run-off with moderate to severe diffuse disease. This patient did show a significant increase in the R2* values in the calf, when it was elevated ($p < 0.0001$).

Groups		Volunteers (24-36 yrs)	Volunteers (55-67 yrs)	Patient 1	Patient 2	Patient 3
n		5	5	1	1	1
Classification		*normal*	*normal*	*I*	*I*	*III*
mean R2* (1/s) calf baseline	R	32.0 ±1.4	31.9 ±1.2	30.1	32.3	**31.8**
	L	32.6 ±1.0	32.5 ±1.2	31.4	32.5	**32.4**
mean R2* (1/s) calf elevation	R	32.6 ±1.2	31.6 ±1.1	29.8	33.1	**40.2***
	L	33.8 ±1.4	32.5 ±1.0	31.4	33.1	**38.2***
mean R2* (1/s) calf elev + exer	R	33.5±1.4	32.2 ±1.0	31.0	33.5	**40.0***
	L	34.2 ±1.6	34.2 ±1.6	32.0	33.4	**37.1***

TABLE 1: * **Statistical significance $p < 0.0001$**

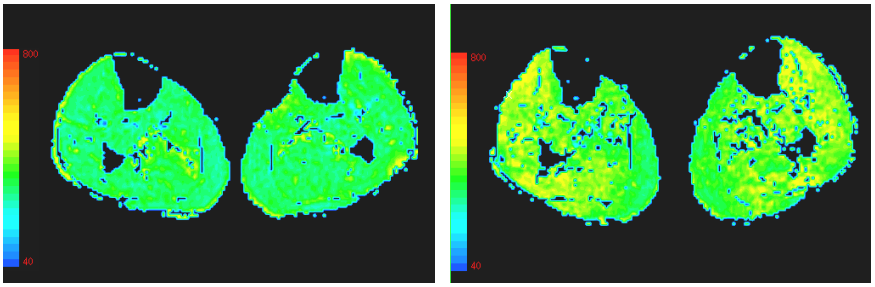

Fig. 1: R2* color maps with blue representing the lowest level of deoxyhemoglobin and red representing the highest level of deoxyhemoglobin (color map scale is the same).The map on the left was acquired at baseline (notice the R2* map is mostly green). The map on the right was acquired after elevation and post exercise, showing a visual increase in yellow on the R2* map, corresponding to an increase in deoxy-hemoglobin levels.

Conclusion:
We have established BOLD data for healthy subjects, without vascular disease, showing no R2* change between baseline and post-exercise imaging. Our preliminary data suggests that in severe vascular disease, stimuli which exacerbate ischemia result in a significant increase in R2*, reflecting a decrease in the relative oxygen content in the calf. Further studies to assess BOLD MRI as an objective measure of tissue oxygenation in the extremities are warranted, as BOLD MRI may potentially be used to functionally assess patient with PVD and monitor their response to treatment.

REFERENCES
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