Functional Perfusion Imaging of Human Retina with Arterial Spin Labeling MRI

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Introduction:
The human retina is a thin layer of light-sensitive tissue located at the back of the eyes and is responsible for sending visual information through the optic nerve to the brain. Retinal perfusion can be disturbed in pathophysiological conditions such as glaucoma, which is characterized by reduced retinal blood flow due to elevated intraocular pressure. Thus the ability to measure retinal perfusion is important for the diagnosis and treatment of the disease. Studies have shown that visual stimulus leads to changes in the retinal blood flow [1] and blood oxygenation level dependent (BOLD) signal [2]. In this study we show that retinal blood flow changes can be measured with arterial spin labeling (ASL) magnetic resonance imaging (MRI).

Methods:
All experiments were performed on a General Electric (GE) 3.0 Tesla EXCITE system (Milwaukee, Wisconsin). Axial images through the orbits at the level of the optic nerve were acquired using a partial Fourier single shot fast spin echo (SSFSE) sequence with FAIR preparation pulses. SSFSE significantly reduced the susceptibility artifacts around the eyes and allowed fast acquisition with high spatial and temporal resolution. A coronal tagging slab is selected to minimize the transit delay of tagged blood. The following sequence parameters were used: TR 4 seconds; TE 60msec; FOV 22cm; matrix size 128x128; single slice; slice thickness 8 mm; repetitions 80; inversion delay TI: 0.3, 1.0, 1.5, 2.0, 2.5 seconds. The otherwise overwhelmingly bright signal from vitreous humor was reasonably suppressed due to the inversion preparation pulses. In addition, fat saturation was applied to reduce the fat signal at the back of the eyes. The visual stimulus paradigm consisted of a block design of a full visual field, maximum-contrast, flashing checkerboard with 40 seconds on, 40 seconds off and 4 cycles. An 8-channel array coil (GE) was used, but only data from the 3 channels proximal to the eyes were used for processing. Perfusion time courses were obtained from the running subtraction of control and tag images. Correlation analysis between the perfusion time courses and the stimulus paradigm with a correlation threshold of 0.2 was used to determine activated pixels. The activation time course was then generated from the activated pixels within the region of interest (ROI) shown in Figure 2A. Signal due to eye motion was estimated by averaging the time courses from pixels selected on the anterior edge of both orbits.

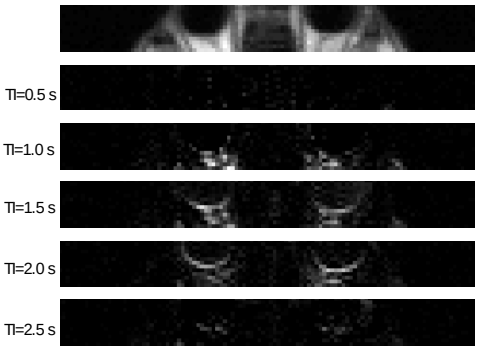

Figure 1. Anatomical and single slice perfusion images acquired at TI=0.5,1.0,1.5,2.0,2.5 sec using SSFSE with FAIR.

Results:
The perfusion maps acquired at different TIs demonstrate the dependence of the perfusion signal on TI (Figure 1), similar to the results obtained by Alsop et al [3]. The perfusion was not seen at TI= 0.3sec and appeared posterior to the retina at TIs =1.0, 1.5secs, and then decayed away as TI increases. At the delay time of 2.0 sec, most tagged blood had reached retina and the perfusion signal started to decrease as shown in the TI=2.5sec image. The activation time course shows elevated perfusion during visual stimulation and the percent signal change is approximately 80% (Figure 2B). Figure 2C shows that the eye movement is not correlated with the stimulus.

Discussion:
Measurement of human retinal perfusion is challenging for several reasons: the retina is approximately 250um thick; the area around the orbits suffers from severe signal loss due to MRI susceptibility; and eye motion is inevitable and can mask the true perfusion signal. However, our preliminary results show that it is feasible to apply ASL to image retinal function. To our knowledge, this is the first functional perfusion study of the retina in humans using MRI.

References:
1. Riva CE, et al, Neurosci Let. 128:291-196, 1991
2. Duong TQ, et al, Investig. Ophthalm. & Visual Sci 43:1176-1181, 2002
3. Alsop DC, et al, ISMRM 8th Mtg p.162, 2000

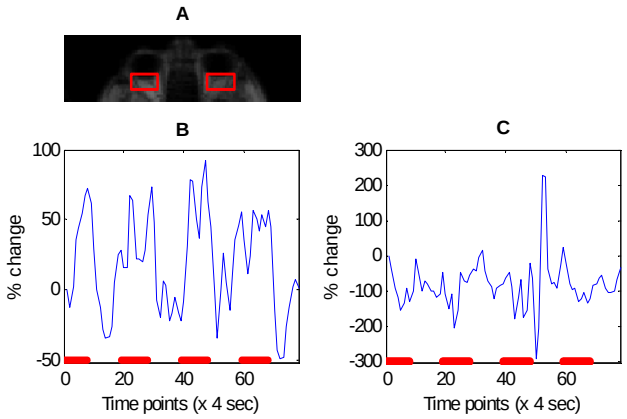

Figure 2: (A) Region of Interest (ROI) overlaid on top of an anatomical image; (B) activation time course within the ROIs; (C) estimated eye movement. The red bars in B and C indicate the time during which visual stimulation is on.