Bold Oxygen Level Dependant (BOLD) Quantitative Susceptibility Mapping (QSM) at Different Head Orientations

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Target Audience: ISMRM attendees interested in quantitative functional magnetic resonance imaging (fMRI) methods.

Introduction: The oxygenation saturation of blood affects its magnetic susceptibility, a quantitative property that can be measured with QSM methods. In this abstract, we examine the use of QSM for measurement of brain activation as compared with traditional R_2* dependent BOLD-fMRI, at different head orientations. In recent years there have been many technical developments with QSM processing, particularly with higher resolution multi-echo imaging [1-4]. A disadvantage of BOLD is that it is primarily a qualitative method for mapping brain activation, which limits interpretation. A QSM time course can be calculated from the phase of echo planar images typically collected in fMRI experiments [3-5]. It is expected that the BOLD-QSM time course will be less sensitive to orientation changes of the head and will produce signals comparable to traditional BOLD signals.

Methods: Imaging was performed on a 3T MR Scanner (Discovery 750, GE Healthcare). Two healthy human subjects were imaged in accordance with our local institutional review board. The imaging included a T_1-weighted anatomical and 2D multi-slice echo planar imaging – where both the magnitude and phase images were acquired. Two acquisitions were performed with the head repositioned via an angular rotation of 5 to 10 degrees about the left-right axis (The subjects were asked to sit up and an extra pad was placed behind the upper portion of their head). Motor (sequential finger tapping) and visual (8 Hz, flashing checker board) stimuli were used for neural activation in 30 s on/off blocks. Sequence parameters for the runs were TR/TE/α of 2000 ms/30 ms/80°. The field-of-view and acquisition matrix were 22.4 cm×22.4 cm×15.1 cm and 64×64×43, respectively; yielding a voxel size of 3.5 mm isotropic. The phase time course was first unwrapped. Then a linear regression was applied to the steady state images (i.e., omitting the first 10 s of the acquisition) to remove the offset and field drift. Polynomial fitting was applied to each volume to remove additional noise [3], which was followed by low-pass filtering to remove physiological noise. The processed phase was used to calculate the induced magnetization and magnetic susceptibility changes. Anatomical images were co-registered to determine the orientation change. Temporal measurements of the BOLD and BOLD-QSM activations were then plotted from individual voxels corresponding to the motor and visual cortex at the different head orientations. The contrast to noise ratio (CNR) and correlation coefficients of the two types were calculated.

Results: The registration coefficients are displayed in Table 1, units are in mm. In Figure 1, plots of BOLD and BOLD-QSM time courses are shown for each subject at each orientation. Upon visual inspection of the plots, we observe comparable activation. Table 2 contains the CNR measurements for the of temporal signal and correlation coefficients. The CNR was higher in the BOLD-QSM runs in 5 of the 8 time courses measured.

Conclusion: From the CNR measurements and plots, we see that the variation is comparable between BOLD and BOLD-QSM, as expected. Although phase-based BOLD measurements have recently been shown at higher field strengths, we demonstrate comparable results with phase-derived activation at 3T [3-5]. We found that the normalized BOLD and BOLD-QSM had good overlap (Figure 1) and we show that BOLD-QSM produced consistent quantitative measurements after head reorientation. BOLD-QSM can be considered as a more quantitative way to preform fMRI.

References: [1] Sun & Wilman, 2014, MRM, 71(3):1151-1157. [2] Bilgic, *et al.*, 2012, Neuroimage, 59(3):2625-2635. [3] Bianciardi, *et. al.*, HBM, 2014, 35:2191–2205 [4] Sun & Wilman, 2014, MRM, Early View. [5] Balla, *et al.*, 2014, Neuroimage. 100:112-124.

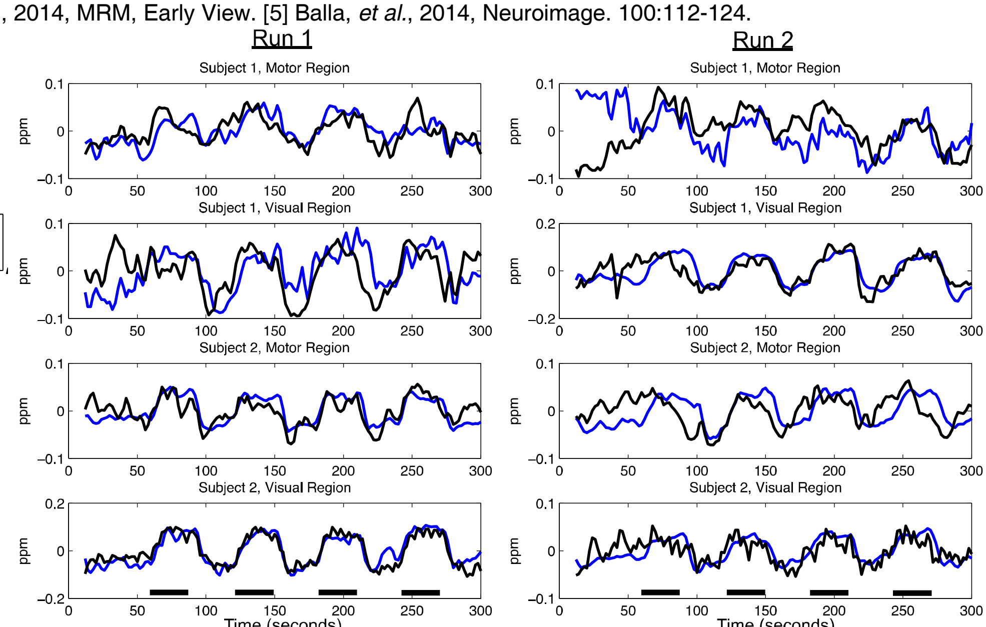

Figure 1: *FMRI time courses. Column 1 represents the first run and column 2 represents the second run after the head is moved. The stimulus duration are shown by the black bars in the bottom row. Note the good agreement between the methods.*

Table 1: *Orientation Changes (mm)*

Movement In Subject 1

X1 = 0.992 X + 0.123 Y – 0.041 Z – 14.328
Y1 = -0.120 X + 0.991 Y + 0.053 Z + 7.643
Z1 = 0.047 X – 0.047 Y + 0.998 Z - 0.426

Movement In Subject 2

X1 = 0.993 X + 0.093 Y – 0.069 Z – 6.157
Y1 = -0.095 X + 0.995 Y – 0.020 Z + 9.533
Z1 = 0.067 X + 0.027 Y + 0.997 Z -13.811

Table 2: *Contrast to Noise and Correlation Measurements.*

		Subject 1				Subject 2			
		Run 1		Run 2		Run 1		Run 2	
		Visual	Motor	Visual	Motor	Visual	Motor	Visual	Motor
CNR	BOLD	1.67	1.69	1.73	2.34	2.54	4.10	3.59	1.76
	BOLD QSM	2.89	2.77	2.06	2.01	3.11	2.99	2.67	3.69
Correlation Coeffiecent		0.42	0.62	0.73	0.27	0.87	0.71	0.63	0.38