Direct comparison of multi-echo BOLD and VASO based fMRI

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Introduction In a recent paper by Lu et al [1] multi-echo BOLD and VASO data were acquired during checkerboard stimulation of the visual cortex. Multi-echo VASO data provides a noninvasive means to extract the changes in CBV, venous oxygenation fraction and oxygen extraction fraction. Comparing multi-echo BOLD and VASO data can shed a light on the relative intra- (IV) and extravascular (EV)contributions to the BOLD effect. Here data are presented for the motor cortex. Lu et al. used multiple runs to obtain VASO and BOLD data. Here the data is acquired in an interleaved fashion making it less sensitive to changes in the underlying physiology and task performance. Eight echoes were acquired instead of the two times two echoes in the Lu et al. paper.

Methods A 2D 8-echo EPI sequence with interleaved acquisition of BOLD and VASO images was implemented on a Philips Intera 3T scanner. Imaging parameters were: TR = 3000 ms, FA = 90˚, TE = 11/ 30/ 49/ 68/ 87/ 106/ 125/ 144 ms, SENSE factor = 2.5, 202 volumes, matrix = 64 x 64, FOV = 224 mm and slice thickness = 3.5 mm. A nonselective adiabatic inversion pulse with TI =890 ms was applied to null the blood signal every other volume (starting with the second volume). A regular multi-slice EPI series was used to locate the motor cortex and to position the BOLD / VASO slice. Nine subjects performed a paced motor task that consisted of opening, and closing of the right hand at a frequency of 0.5 Hz. A total of 10 blocks each consisting of 10 volumes rest followed by 10 volumes motor task were obtained. The BOLD / VASO series was run twice with the transitions in the task either synchronised to the BOLD volumes or to the VASO volumes to avoid a possible bias in the analysis. The data were analysed using IDL. After splitting the data into separate BOLD and VASO series, each series was realigned using the first echo and applying the realignment parameters to the other echoes. All data sets were spatially smoothed with a 2D Gaussian filter with a FWHM of 2.5 voxels and highpass filtered to remove any baseline drifts. T_2^*, and S_0 maps were calculated [2] by fitting a mono exponential to the signal at the eight echo times. Further analysis was restricted to a manually segmented area around the motor cortex. Activation maps were obtained by applying multiple regression. Threshold for activity was the critical t-value corresponding to $p<0.05$ (Bonferroni corrected) and a minimal cluster size of 2. Averaged signal changes, total and EV R2*, change in CBV upon task execution, and venous oxygenation fraction (Y_v^{act}) and oxygen extraction fraction (OEF^{act}) during the motor task, were calculated for the intersection mask of the BOLD T2* and VASO S_0 activation maps (i.e. for the capillary EV VASO region). The physiological parameters were calculated using the formulas of reference [1] and assuming $CBV^{rest} = 4.7\%$, $Y_v^{rest} = 0.61$ and $OEF^{rest} = 0.38$.

Results Figure 1 shows the activation maps based on total BOLD (T_2* BOLD data), EV BOLD (T_2* VASO data) and VASO (S_0 VASO data) effect. Averaged time courses for both BOLD and VASO T_2* and S_0 data are shown in figure 2. Table1 summarizes the averaged EV and total R_2*and ΔR_2* values. Table 2 reports the calculated physiological parameters.

Discussion. The activated area based on the EV BOLD effect was consistently smaller than the area based on the total BOLD effect in all subjects (figure 1). This is to be expected given the reduced CNR of VASO data compared to BOLD data. The averaged time courses (figure 2) do not show any differences in onset when scaled to the same level (not shown here). Lu et al. found a bigger change in total R_2* than in EV R_2* upon activation. Here the opposite is found. At least this does not support the conclusion that there is a large intravascular contribution to the BOLD effect in the motor cortex at 3T. The ΔCBV value reported here is almost half the value found by Lu et al. while the other physiological parameters are comparable.

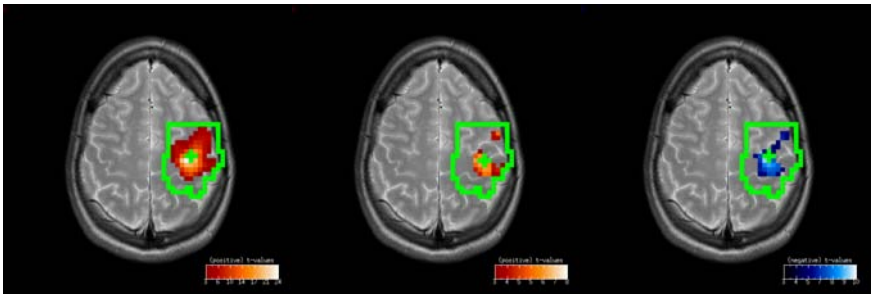

Figure 1: Activation maps for (left) total BOLD effect, (middle) extravascular BOLD effect and (right) VASO effect. The thick line shows the segmented area and the cross the centre of mass of the activated area.

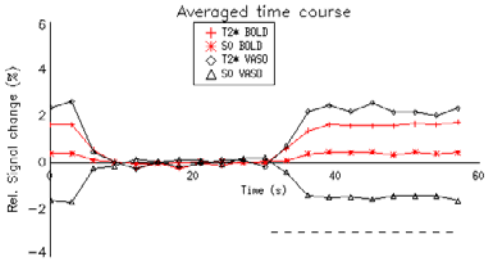

Figure 2: Averaged time courses. The dotted line shows the period of motor activation.

EV $R_{2,rest}$* (s^{-1})	EV ΔR_2* (s^{-1})	Tot. $R_{2,rest}$* (s^{-1})	Tot. ΔR_2* (s^{-1})
22.8 ± 2.2	-0.50 ± 0.14	23.8 ± 3.2	-0.36 ± 0.07

Table 1: Extravascular (EV) and total relaxation rates averaged over all subjects (n=9) and measurements.

#voxels	ΔCBV(%)	Y_v^{act}	OEF^{act}
13 ± 9	30 ± 5	0.75 ± 0.02	0.24 ± 0.02

Table 2: Calculated physiological parameters averaged over all subjects (n=9) and measurements.

References: [1]: Lu H (2005) Magn.Res.Med. 53:808-816; [2]: Speck O (1998) Magn.Res.Med. 40:243-248.