# Correlation between Venous Blood T1 and BOLD FMRI in Young and Elderly Subjects

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**Introduction:** Although BOLD functional MRI (fMRI) has been widely applied for sensorimotor and cognitive brain mapping, relatively large variations in BOLD signals have been observed between subjects, which may result in a reduction in the statistical power in group analysis as well as comparisons between patient and control populations. Recent studies have begun to address the biophysical basis underlying the inter-subject variations of BOLD fMRI. In particular, venous oxygen saturation measured by venous blood T2 has been found to correlate with BOLD activation and may be used to normalize BOLD signals [1]. Blood T1 has a strong dependence on hematocrit (Hct) which is a scale factor of the magnitude of BOLD fMRI signals [2]. In this study, we investigated the relationship between in vivo blood T1 measurement and BOLD activation during visual stimulation in 2 groups of young and elderly subjects.

**Materials and Methods:** MRI experiment: All MR imaging experiments were performed on a Siemens Tim Trio 3T (Erlangen, Germany) using 12-channel head coil. A total of 22 subjects including 11 young volunteers (age 22±2 yrs, 5 males) and 11 elderly subjects (age 67±5 yrs, 5 males) participated in this study after they provided written informed consent. All the participants had no neurological or psychiatric illness. A segmented multiphase Inversion recovery (IR) TrueFISP sequence was used for venous blood T1 measurements at the level of superior sagittal sinus [3]. The imaging parameters were: TR = 3.48 msec, TE = TR/2, FOV = 22 cm, matrix = 128 × 128, a single 5-mm axial slice, 53 phases between the TI of 140 ms to 5012 ms with a step of 94 ms were acquired within 50s. For BOLD fMRI, a block design with 10 Hz flashing checkerboard was used to stimulate the visual cortex with a sequential 30-s OFF/ON paradigm (eight cycles). Ten oblique slices with thickness = 5 mm and gap = 1 mm were scanned, with the slices parallel to the anterior–posterior commissure (AC-PC). The scan parameters were TE = 30 ms, TR = 2s, FOV = 22 cm, matrix = 64 × 64, bandwidth = 2442 Hz/pixel.

Phantom Experiment: Validation studies of the IR-trueFISP sequence were performed using a flow phantom filled with distilled water doped with 0.05 mM/L $MnCl_2$ and 0.2 mM/L NaCl (T1=1473ms, T2=163ms). Four velocities were tested: 6, 10, 13, 17cm/s within the range of human venous blood flow.

Data processing: For venous T1 quantification, IR TureFISP signals were extracted from regions-of-interest of mid-sagittal venous sinus, and fitted using a standard 3 parameter IR model, and the same fitting procedure was done to the flow phantom data. Functional MRI data were analyzed by SPM2. Activated voxels were detected at the significance level of $p<0.05$ with at least 20 contiguous voxels in each subject. Task-induced signal changes were calculated within ROIs of activated clusters in the visual cortex. Two sample t-test with or without including venous blood T1 as a covariate was used to compare BOLD activation between the two age groups. Further, the interaction between blood T1 and group was included as an additional covariate.

**Results:** The mean estimated T1 of flow phantom was 1493±16ms within the velocity range of 6-17cm/s, indicating the accuracy of the IR-trueFISP measurement (T1=1473ms determined using conventional IR scans). The mean venous blood T1 value was 1860±97ms and 1929±112ms for the young and old groups, respectively. Robust fMRI activations were detached in all subjects. Fig1 shows the scatter plots of venous blood T1 and the BOLD signal change in visual cortex ROI across subjects. There was significant negative linear correlation ($r = -0.57$, $p<0.01$). Using two-sample t-test, we observed significantly greater activation in visual cortex in the young group than in the old group. However, when blood T1 was included as a covariate, the peak and mean t-values decreased (Table 1). Besides, including the interaction between T1 and age group caused further decrease in the statistical significance between two groups.

| Group comparison | $t_{max}$ | $t_{mean}$ | Activated pixel number |
|---|---|---|---|
| Two-sample t-test | 5.62 | 3.97 | 293 |
| with the regression of T1 | 5.33 | 3.97 | 326 |
| with the regression of T1 and the interaction between T1 and group | 4.71 | 3.88 | 104 |

***Table 1.*** The statistical results of the comparison between the young and old groups

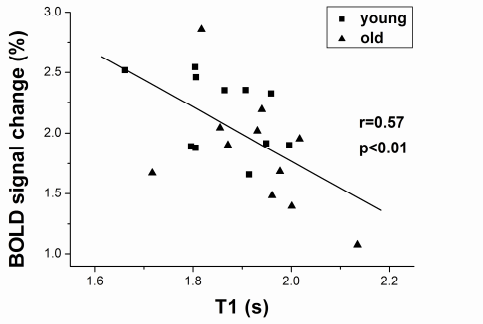


***Fig1.*** Scatter plot of venous blood T1 and BOLD signal changes in visual ROI.

**Discussion:** To the best our knowledge, this is the first report of negative correlation between blood T1 and BOLD activation. Such relationship is expected since Hct scales BOLD signal changes and is inversely related to blood T1 [2]. The results suggest blood T1 may be applied to "normalize" BOLD fMRI. However, the reduced statistical significance between visual cortex activation between the 2 age groups by including blood T1 as a covariate suggest that the observed age effects on BOLD activation may be partly due to variations in physiological parameters such as Hct between age groups.

**References:** [1] Lu H, Human Brain Mapping 2009; [2] Lu H, Magn Reson Med 2004; 52:679-682. [3] Wu W-C and Wang J. ISMRM 2008, #3080