On the effect of flow and modest diffusion weighting in fMRI

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Introduction One of the unresolved puzzles with respect to the BOLD contrast is the question of the relative contributions of the intra- and extra-vascular components to the signal at a given field strength [2]. Several studies have used flow (FW) and diffusion weighting (DW) in an attempt to tackle this problem. A common result of these studies is a reduced BOLD signal when FW or DW is applied [1]. Usually, the loss of the intravascular BOLD component due to FW or DW is given as an explanation for the observed effect. Here an alternative explanation is presented using a newly developed method which allows a cyclic variation of the amount of FW or modest DW over the scanned volumes in a fast multi-echo (6 echoes times 19 slices within 3 seconds) SENSE EPI sequence.

Methods A flow sensitised 6-echo gradient echo SENSE EPI sequence was implemented on a Philips Intera 3T scanner. A bipolar gradient pair was introduced on all three gradient axes before the EPI readout to accomplish FW or DW. Two different series were scanned: one with FW and one with modest DW. Imaging parameters of the first series were: TR = 3000 ms, FA = 90˚, TE = 28.0/ 48.3/ 68.6/ 89.0/ 109.3/ 129.6 ms, SENSE factor = 2.0, 234 volumes, matrix = 64 x 64, FOV = 224 mm, 19 slices with 3.5 mm thickness, and no slice gap. The strength of the gradient pair was cyclic varied, resulting in no FW and FW with v_{crit} = 2.2, and 1.6 cm/s (b = 0/ 2.2/ 4.4 s/mm^2 respectively). Imaging parameters of the second series were: TE = 40.0/ 57.1/ 74.2/ 91.2/ 108.3/ 125.4 ms, SENSE factor = 2.5, and cyclic varying DW of b=0/ 35/ 70 s/mm^2 the remaining parameters were identical to the first series. Six subjects performed a paced motor task that consisted of opening, and closing of the right hand at a frequency of 2 Hz. A total of 9 blocks each consisting of 13 volumes rest followed by 13 volumes motor task were obtained. Total scan time per series 11m42s.
The data were analysed using IDL (RSI Boulder, Colorado), T_2^*, and I_0 maps were calculated [3]separately for each amount of FW or DW. Average signal changes were calculated using a mask that contained all clusters of at least 5 voxels with a t-value above 4 ($p<0.05$ Bonferroni corrected) on all three FW or DW T_2^* parameter maps.

Results A decrease in functional signal change occurred at the individual echo times when FW or DW was applied. Table 1 & 2 show the average signal changes based on data of the first echo (ΔS) or using the calculated T_2^* and I_0 parameter maps. The initial intensity decreased upon activation when FW or DW was applied ($p<0.002$, paired t-test). The figure shows the activation maps overlaid on an anatomical image for one typical subject. At TE=28ms the size of the activated area in the motor cortex is clearly reduced when FW is applied while the area remains nearly constant when the calculated T_2^* data is used. Similar results are found when DW is applied.

Discussion The decrease in functional signal change at the individual echo times is in agreement with the literature [1]. However, the functional results based on the T_2^* and I_0 maps presented here show that the observed signal decrease is a result of a reduced initial signal upon activation and that the BOLD effect (T_2^*) is hardly influenced by FW or modest DW. The reduction of ΔI_0 upon activation can be explained by the increased rCBF and rCBV during execution of the motor task. This implies that the intravascular contribution to the BOLD effect at 3T is negligible.

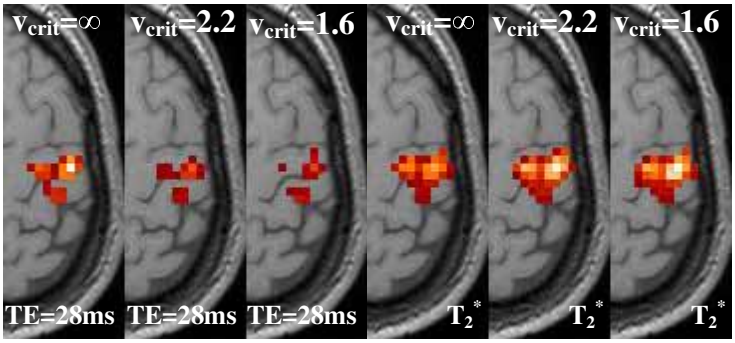

Figure: The effect of FW on data at TE=28ms and on the calculated T_2^* maps.

v_{crit} (cm/s)	*#voxels mask*	*ΔS (%) (TE=28ms)*	*ΔT2(%)*	*ΔI0(%)*
∞	514	1.2 ± 0.1	2.7 ± 0.5	-0.3 ± 0.3
2.2	617	1.0 ± 0.1	2.9 ± 0.5	-0.5 ± 0.3
1.6	534	1.0 ± 0.1	2.8 ± 0.4	-0.6 ± 0.3

b (cm/mm^2)	*#voxels mask*	*ΔS (%) (TE=40ms)*	*ΔT2*(%)*	*ΔI0(%)*
0	198	2.5 ± 0.5	4.3 ± 0.7	-0.6 ± 0.4
35	186	2.1 ± 0.4	4.6 ± 0.7	-1.1 ± 0.4
70	179	1.9 ± 0.4	4.3 ± 0.8	-1.0 ± 0.2

Table 1 & 2: Relative signal changes averaged over subjects (n=6). Left for FW, right for modest DW.

References: [1]:Song AW (1996) Magn.Res.Med.35:155-158; [2]:Hoogenraad FG (2001) Magn.Res.Med. 45:233-246; [3]: Speck O (1998) Magn.Res.Med. 40:243-248.