Functional Brain Imaging using T1rho Dispersion

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Purpose: To investigate $T_{1\rho}$-dispersion as a contrast mechanism for functional brain imaging. $T_{1\rho}$-weighted imaging has recently been suggested to be sensitive to activity-evoked pH changes in the brain, while being relatively insensitive to blood oxygenation compared to conventional T_2*-weighted BOLD imaging[1]. Comparing $T_{1\rho}$- and T_2-weighted imaging (which can be regarded as a special case of $T_{1\rho}$ in which the spin-lock frequency is zero) allows us to determine the effect of the spin-lock pulse (the $T_{1\rho}$-dispersion) while holding all other parameters constant.

Methods: A spin-lock prepared spin-echo EPI sequence was developed on a Philips 3T Achieva TX scanner. $T_{1\rho}$-weighting was produced by non slice-selective $90°_{+x}$–SL_{+y}–$180°_{+y}$–SL_{-y}–$90°_{+x}$ magnetization preparation[2], where SL represents the spin lock pulses with a frequency of 500Hz and duration of 50ms each, (total spin-lock time 100ms). T_2-weighting (spin lock frequency of zero) was produced by setting the spin lock RF amplitude to zero. Data readout was using a single-slice spin-echo EPI technique with TE/TR=14/3000ms, matrix 84x84, 240mm FOV, 10mm slice thickness. The functional paradigm consisted of 5 epochs of (24s off/24s on) checkerboards flashing at a frequency of 15Hz. A total of 4 runs of $T_{1\rho}$- and T_2-weighted imaging were acquired from a single subject in two sessions, with the order of presentation counterbalanced between sessions. Data was analyzed with a general linear model using SPM8 with a canonical HRF[3].

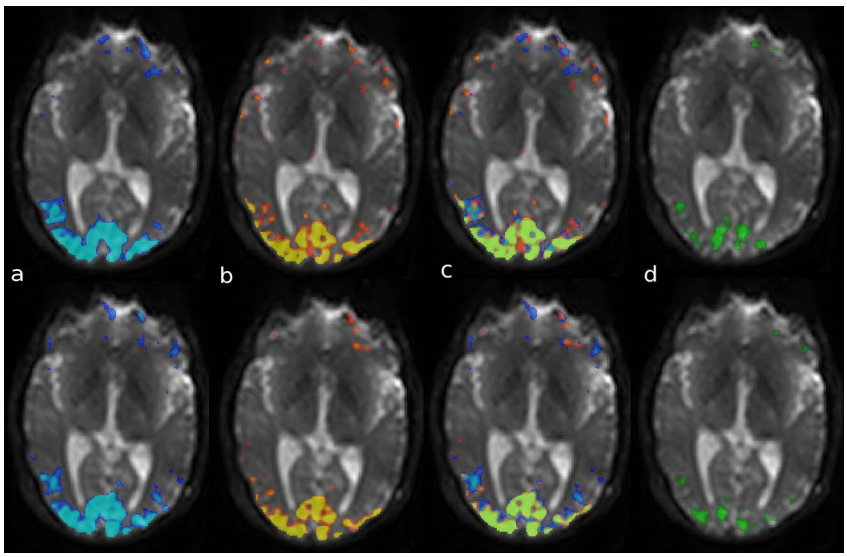

Figure 1. Activity measured using (a) T2-weighting, (b) $T_{1\rho}$, (c) T2 and $T_{1\rho}$ overlaid, and (d) $T_{1\rho}$-dispersion. All maps thresholded at $p<0.001$ (uncorrected). Top and bottom rows show data from different sessions but the same subject.

Results: The baseline signal intensity with 500Hz $T_{1\rho}$-weighting was approximately 40% higher than with T_2-weighting, consistent with appropriate spin-locking. Maximum signal intensity changes were ~2% and ~3% for $T_{1\rho}$- and T_2-weighting respectively. While the activation maps are similar (Figure 1a-c), consistent regions are observed in which the activation is significantly higher with T_2-weighting (cluster $p<0.05$, FWE corrected, Figure 1d). No regions were observed with significantly greater activation using $T_{1\rho}$-weighting.

Discussion: The subtle but consistent differences between the maps may be an indication of better spatial localization in the 500Hz $T_{1\rho}$-weighted data, consistent with a shift in weighting towards pH and away from BOLD contrast. However, the slice thickness used may partly obscure any improved localization.

Conclusion: Functional brain imaging using $T_{1\rho}$- and T_2-weighted imaging provide qualitatively similar maps, but with some regions of significant difference ($T_{1\rho}$-dispersion), perhaps due to differences in the contrast mechanism. Further work with an improved interleaved acquisition of different spin-lock frequencies will investigate whether $T_{1\rho}$-frequency dispersion can further disentangle pH and oxygenation-related contrast.

References: 1. Magnotta, V.A. et al, Detecting activity-evoked pH changes in human brain. PNAS 109(21) 8270-8273. 2. Witschey, W.R. et al, Artifacts if T1rho-weighted imaging: compensation for B1 and B0 field imperfections. J.Magn.Reson. 2007 186(1) 75-85. 3. Friston, K.J., Statistical parametric mapping: ontology and current issues. J Cereb.Blood Flow Metab. 15(3): 361-370.