Human fMRI at 9.4 T: Preliminary Results

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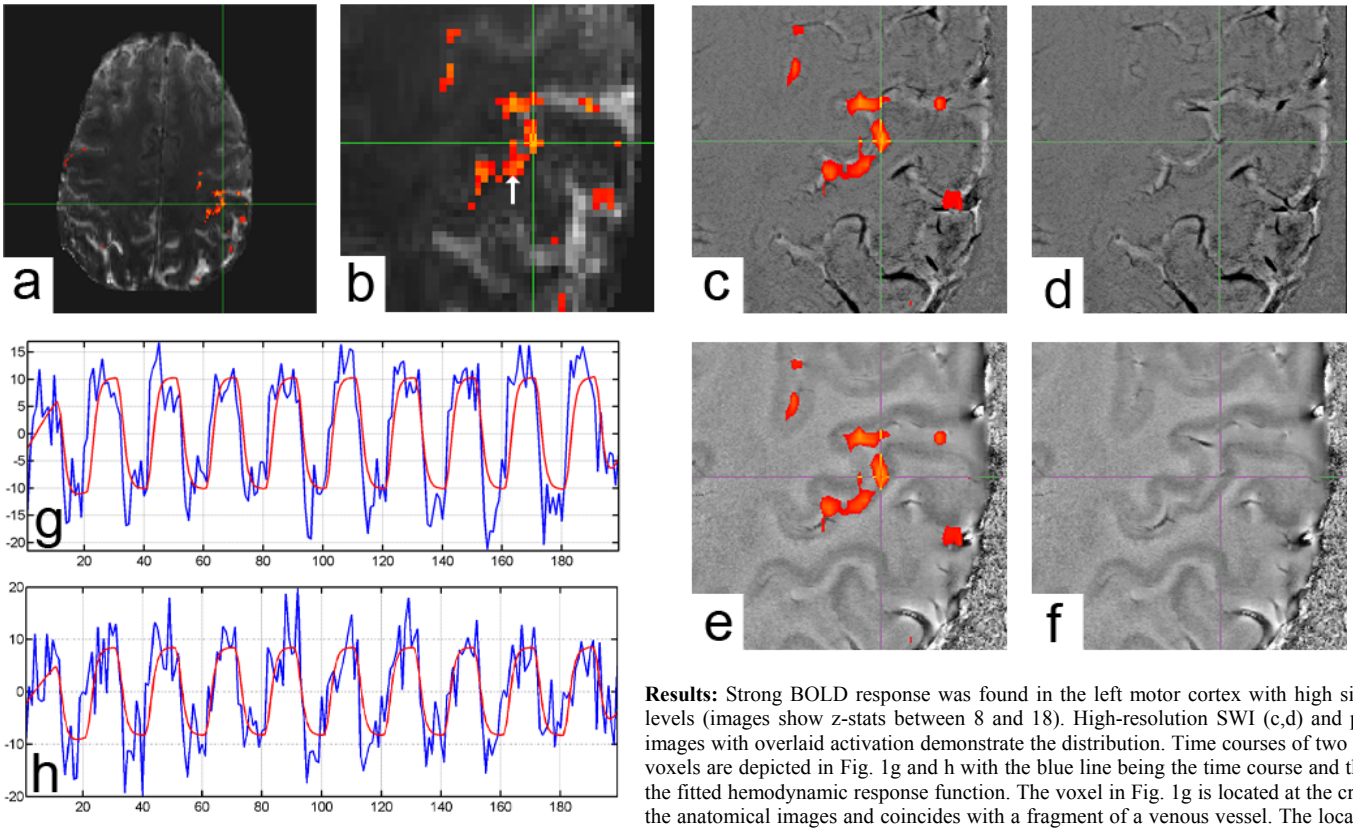
Introduction: With increasing field, the MR signal-to-noise ratio is expected to grow linearly, while a BOLD increase of more than linear is expected [1]. In addition, a higher emphasis on signal from microvasculature is predicted, especially for SE-EPI [2,3], while GE - EPI remains more specific to the macrovasculature. Here, a field strength of 9.4 T is used for the first time to measure BOLD activation during finger tapping of a human subject. To examine the signal contributions of tissue and veins, the functional maps were overlaid on T2*-weighted GRE images revealing venous vasculature at high detail. Co-registration of both image modalities demonstrates where the functional signal coincides with venous structures.

Subjects / Methods: Data were acquired on three subjects at a 9.4 T scanner (Siemens Medical Solutions, Germany, gradient strength 40 mT / m, slew rate 333 mT / (m ms)) using a 16-channel transmit/receive coil. The sequence was based on GRE-EPI, incorporating a point spread function correction pre-sequence [4]. Scan parameters were TR = 2000 ms, FOV 210 mm, matrix size 190 x 190, voxel size 1.1 mm isotropic, BW 1755 Hz / pixel, 20 slices, 200 repetitions and a partial Fourier factor of 6/8. An echo time of 35 ms was reached without parallel imaging. The paradigm consisted of finger tapping with the right hand, alternating between 20 s of tapping and 20 s of rest.
For analysis, the data were processed with FSL FEAT [5] after manual brain extraction. Parameters used were motion correction, no smoothing, a standard hemodynamic response function, temporal filtering and motion parameters as additional confounds.
Additionally, high-resolution magnitude and phase images were acquired in the same session with a 3D GRE sequence. Sequence parameters were TE = 20 ms, TR = 27 ms, FOV 180 mm x 146 mm, matrix size 896 x 728, voxel size 0.2 mm in-plane, slice thickness 1.1 mm. A total of 48 slices was acquired with parallel imaging settings of GRAPPA 2 with 128 reference lines, and partial Fourier factor of 6/8, 3 repetitions were recorded. The data were then co-registered with FSL FLIRT and averaged. Phase and susceptibility-weighted images were computed as described previously [6]. Finally, EPI data were co-registered on the high-resolution SWI and phase images.



Results: Strong BOLD response was found in the left motor cortex with high significance levels (images show z-stats between 8 and 18). High-resolution SWI (c,d) and phase (e,f) images with overlaid activation demonstrate the distribution. Time courses of two exemplary voxels are depicted in Fig. 1g and h with the blue line being the time course and the red line the fitted hemodynamic response function. The voxel in Fig. 1g is located at the cross hair in the anatomical images and coincides with a fragment of a venous vessel. The location of the second voxel is indicated by the white arrow in Fig 1b and does not seem to be close to a vein. Activation reaches 20 % with a z-statistical value of 15.8 in Fig. 1g and around 16 % with a z-statistical value of 11.8 in Fig. 1h.

Discussion and Conclusion: Here we show the feasibility of functional imaging at 9.4 T for a simple motor paradigm. Highly significant BOLD activation was found, located mainly within gray matter. Contributions which seem to arise from CSF may be due to partial volume effects as well as to veins close to the edge of the cortex. Strong activation is also found in regions without veins, although macrovasculature still causes higher functional signal which may be attenuated by using SE-EPI.

References: [1] Gati et al, Magn Reson Med. 2005; 38:296:302 [2] Uludag et al, NeuroImage 48 (2009) 150–165 [3] Yacoub et al, Neuroimage 2005;24(3):738-750 [4] Zaitsev et al, Magn Reson Med 2004; 52:1156-66. [5] Woolrich et al, NeuroImage, 45:S173-186, 2009. Smith et al, NeuroImage, 23(S1): 208-219, 2004.[6] Budde et al, Magn Reson Med. 2010 Sep 24. [Epub ahead of print]