Introduction

A limitation of $T_2^*$-weighted BOLD MRI is the confounding contribution of signal from the larger vasculature. An improved BOLD specificity to parenchyma can be achieved at high field strengths such as 7T due to increased contrast-to-noise ratio, and reduced contribution of intravascular signal as compared to lower field strengths. Moreover, at 7T high spatial and temporal resolution of the BOLD signal can be achieved [1], making it possible to investigate the BOLD response in much finer detail. Previous human work at 3T has shown that the temporal characteristics of the BOLD response in the visual cortex are related to the organization of the local vasculature [2]. A correlation of the time-to-peak (TTP) and width (FWHM) of the BOLD response function was shown. Based on this previous work we expect to obtain a better separation between parenchyma and the macrovasculature at a high resolution. We characterized the spatio-temporal properties of the BOLD response in the visual cortex at 7T using an event-related fMRI paradigm with very short visual stimuli, higher sampling rate, and for different spatial resolutions.

Materials and Methods

Data acquisition: Five healthy volunteers were scanned on a Philips 7T system with a 16 channel SENSE head coil. Functional data was obtained using a multislice single-shot GE-EPI acquisition with TR/TE=440/27ms, FA=60°, SENSE factor=2.2, four different isotropic voxel sizes with dimensions: 1, 1.5, 2 and 2.5 mm with slice gap 1.5mm, 1mm, 0.5mm and 0mm respectively; FOV=150×120 mm², and 7 coronal slices (3 slices for the 1mm scan) covering visual areas V1 and V2. The bandwidth in the phase-encode direction was set to 2300Hz for all voxel sizes, to ensure the same geometric distortions. 3rd order correction of motion was performed. The localizer part was processed realigned, corrected for cardiac and respiratory fluctuations and linear trend [5, 6]. The localizer part was processed using FEAT: high pass filtering (cut-off at 1/31.6 Hz.), slicing time correction, and no spatial smoothing [7]. The largest significant cluster (cluster P threshold = 0.05, Z threshold=3.5) was selected and used as a region of interest for the ER-fMRI analysis for the corresponding voxel size. A vein region mask was created on the 1.5 mm³ scan as an anatomical reference. Cardiac and respiratory rate data were recorded during all scans. Functional Paradigm: Each functional scan consisted of four parts; i) 31s baseline period, ii) 437s event-related (ER) part, iii) 31s baseline period and, iv) 79s block design (localizer) part with off/on periods=15.8/15.8s (uniform gray screen / 8Hz reversing checkerboard). The event train for the ER part was generated with interstimulus intervals (ISI) taken from a uniform permutation of 1st to 7th ISI taken from a uniform permutation of 1st to 7th ISI with a fixed ISI=6s.

Results

The average correlation between TTP and FWHM across subjects and voxelsizes for all active voxels (vein and non-vein compartment) was 0.43±0.16, in agreement with previous results [2]. Overall the TTP, FWHM and MPC values were higher for the vein compartment. The TTP and FWHM distributions became broader with decreasing voxel size. The TTP distributions for the non-vein compartment for all voxel sizes are shown in figure 1 for a representative subject. Figure 2 A-D illustrates the increased TTP spatial heterogeneity with decreasing voxel size. The smallest voxelsize the slow responses (in red) were predominantly localized along the sulci, while the fast responses (in blue) were predominantly localized in neighbouring parenchyma. This correspondance to the underlying anatomy was reduced with increasing voxelsize (see phase image of $T_2^*$'w for underlying anatomy in figure 2-E).

For the non-vein compartment the average BOLD responses are shown for all compartments in figure 3. These findings were similar for all subjects.

Discussion

For the ‘non-vein’ compartment it is apparent that the increasing width of the TTP distribution with decreasing voxelsize reflects more TTP heterogeneity when scanning at a higher resolution. It is seen that at 7T, using short stimuli, small isotropic voxels and high sampling rate, a temporal resolution of the BOLD response can be measured which allows for better separation of vasculature and parenchyma. This opens the possibility to probe layer specific TTP as shown previously in rats [10].

References