Anatomical Identification of V5 in Humans at 7 T

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Introduction: Cortical areas are known to differ in their cytoarchitecture, myeloarchitecture, cortical thickness, vascularity, and regional transmitter/receptor distribution. The goal of this study was the identification of the visual motion area V5, also known as MT [1, 2, 3] as this area shows a regionally increased myelination. The earliest MRI study to show myeloarchitectural differences in grey matter demonstrated that the densely myelinated stria of Gennari demarcating primary visual cortex (V1) was MR visible [4]. Similar studies were performed at field strengths of 3 T [5, 6] and 4.7 T [7]. V5 has also recently been identified using structural MRI at 1.5 T [8, 9]. Using ultra-high field MR scanners it is now possible to examine the human cortex *in vivo* at a resolution of a few hundred micrometers with an adequate signal-to-noise ratio (SNR) and within a reasonable scanning time. In the present study a Turbo-Spin Echo (TSE) sequence was used for visualization of the cortical layers in V5 at 7 T. During a TSE echo-train any imaging slice experiences many off-resonant pulses, which generates magnetization transfer contrast (MTC) [10,11]. Combined with the T_2-weighting and the proton density contrast (by using a relatively short echo time) MTC further helps to map myelinated cortical layers.

Method: All experiments were performed on a 7 T whole-body MR scanner (MAGNETOM 7T, Siemens Healthcare Sector, Erlangen, Germany). An 8 channel phased array head coil (RAPID Biomedical, Rimpar, Germany) was used. All *in vivo* studies were carried out in accordance with ethics approval from the local university, and informed consent was obtained before each study. 17 coronal images covering the region where V5 is expected to lie were acquired using a first TSE protocol (TSE I: TR = 8.3 s, TE = 27 ms, refocusing flip angle = 120°, 2 averages, isotropic voxel size (0.5 mm)³, slice gap 0.25 mm). To assure that the visualized layer structure was not a motion artifact, a second set of TSE images was acquired with different parameters (TSE II: TR = 8.71 s, refocusing flip angle = 180°, slice gap 0.0 mm, other parameters were equal). The slice gap of zero allowed for a complete coverage of V5. Finally, a functional MRI experiment was performed to confirm the location of V5. A moving star field paradigm (block design: 8 repetitions moving star field vs. 8 repetitions static star field, 112 repetitions in total) and an EPI sequence (TR = 3.0 s, TE = 25 ms, flip angle = 90°, isotropic voxel size (1.4 mm)³, GRAPPA reconstruction, acceleration factor = 4) were used to functionally identify V5.

Results: In Fig. 1 a coronal image acquired with the first TSE sequence shows a layer structure in V5 (highlighted by arrows). Four sections of coronal images acquired with TSE sequence II covering the extent of the layer structure in anterior-posterior direction are shown in Fig. 2. The structure is clearly visible in both hemispheres. The uppermost image (A) has the same slice position as the image shown in Fig. 1. Fig. 3 shows the activation pattern acquired with the described fMRI experiment overlaid on the same TSE images as shown in Fig. 2 (A)-(D). The activation pattern nicely corresponds with the region of the layer structure in the TSE images. Similar results were obtained with other subjects (not shown here).

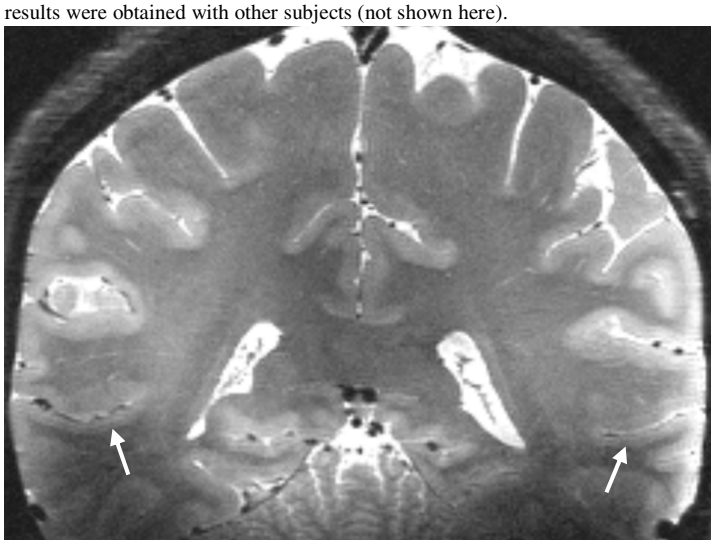

Fig 1. Coronal image of V5 obtained with TSE sequence I.

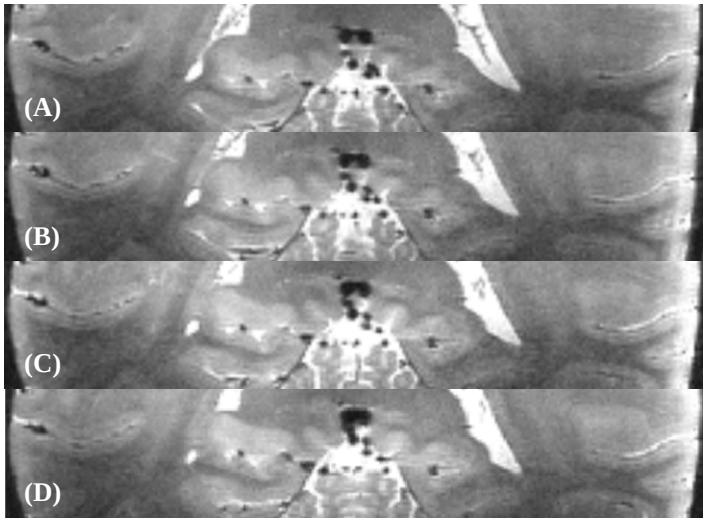

Fig. 2. Sections of coronal images going anterior-posterior (A)-(D) along V5 obtained with TSE sequence II.

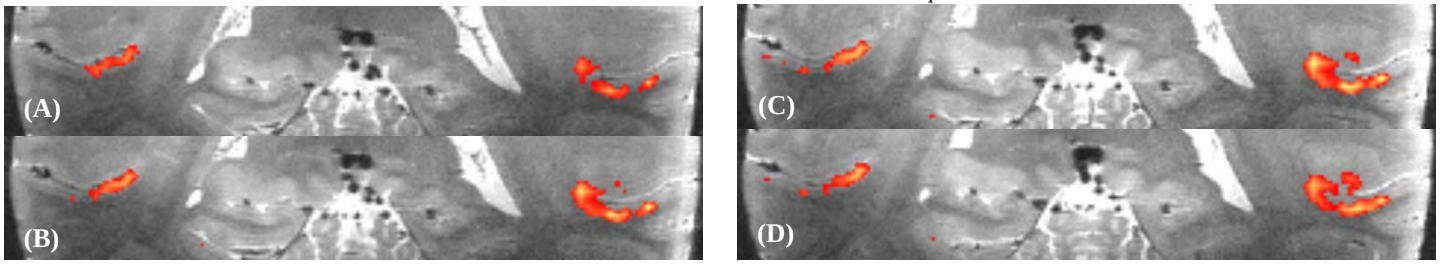

Fig 3. Activation pattern acquired with the described fMRI experiment overlaid on images obtained with TSE sequence II (going anterior-posterior (A)-(D) along V5).

Discussion and Conclusion: Using ultra-high fields such as 7 T enables the mapping of myeloarchitectural differences in grey matter in a reasonable scan time (9-10 min). The high SNR at these field strengths can be "invested" in an increased resolution. Using a Turbo-Spin Echo sequence with an isotropic resolution of 0.5 mm allows identification of the additional myelination within cortical layer 4 which defines V5 anatomically. Because the layer structure is visible in subsequent sequences with different parameters, a motion artifact is highly unlikely. Additionally, the fMRI activation pattern nicely fits the area of the visible layer structure. The results are reliable and reproducible over different subjects. However, it has to be mentioned that subject motion can easily spoil the mapping of the structure because of the high-resolution of the imaging sequence.

References: [1] Zeki S et al, J Neurosci 1991;11:641-9. [2] Watson JDG et al, Cereb Cortex 1993;3:79-94. [3] Dumoulin SO et al, Cereb Cortex 2000;10:454-63. [4] Clark VP et al, Cereb Cortex 1992;2:417-24. [5] Clare S et al, Proc ISMRM 2003;11:658. [6] Barbier EL et al, Magn Reson Med 2002;48:735-8. [7] Logothetis N et al, Neuron 2002;35:227-42. [8] Walters NB et al, Proc Natl Acad Sci USA 2003;100:2981-6. [9] Walters NB et al, Hum Brain Mapp 2007;28:1-8. [10] Melki PS et al, Magn Reson Med 1992;24:189-195. [11] Thomas D et al, Magn Reson Med 2004;51:1254-64.