Isotropic High Resolution Diffusion-Tensor Imaging in Humans at 7T

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Introduction: High resolution diffusion-weighted imaging (DWI) and therefore fiber tractography is a challenge at ultra-high field strength. With higher field strength and resolution, susceptibility effects and T2* decay cause increased distortions, drop-outs and image degradation of single-shot EPI (ss-EPI) acquisitions. Parallel imaging can be used to improve the image quality of ss-EPI [1]. However, parallel imaging is not without its limitations and even with large phased arrays it is still hard to obtain high acceleration

Fig 1: Anatomical image overlaid with the vector-orientations, derived from the ZOOPPA DTI data set.

factors (AF). It has been recently shown that DTI with 1.4 mm isotropic resolution can be achieved at 7T by combining a reduced FOV approach (zoomed imaging) with parallel imaging (GRAPPA) [2]. 'Zoomed imaging with GRAPPA – ZOOPPA', was used to achieve very high AFs of up to seven. In the current study, we are using ZOOPPA to achieve lower AFs, with high image quality, enabling 1 mm isotropic DWI at ultra-high field strength. To demonstrate the usefulness of ZOOPPA, in vivo diffusion-tensor imaging (DTI) results with 1 mm isotropic resolution of the human brain are shown.
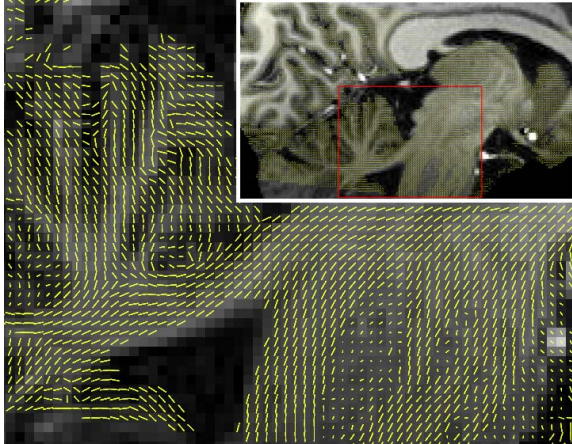
Methods: All experiments were performed on a 7T whole-body MR scanner (MAGNETOM 7T, Siemens Healthcare Sector, Erlangen, Germany) with a 24-element phased array head coil (Nova Medical, Wilmington, MA, USA). Informed consent was obtained before each study. DW images were acquired with a unipolar Stejskal-Tanner sequence: TR = 9500 ms, TE = 72 ms, FOV = 141x191 mm^2, partial Fourier = 5/8, isotropic resolution 1.0 mm^3, 71 slices with 10% overlap, DW with b = 1000 s/mm^2, 60 directions and 6 averages. For OVS a SKEWED pulse was used as proposed in [3,4] and for the GRAPPA reconstruction a 2D convolution kernel [5] with three source points along the readout direction and two source points along phase encoding (PE) direction was used with an GRAPPA AF of three. The total acquisition time was 69 min. The DWIs were corrected for subject motion and registered to the T1 weighted anatomical scan. For all acquisitions, fat suppression was applied using the Ivanov method [6].

Results and Discussion: PE direction was chosen A-P to obtain less pronounced, symmetric distortions. For the head geometry of the volunteer examined in this study a FOV of 200 mm would be necessary to avoid aliasing in PE direction. With the zoomed approach using OVS we were able to use a reduced FOV of 141 mm, which corresponds to a zoomed AF of 1.42. In addition GRAPPA with an AF of three was applied to the reduced FOV acquisition resulting in a net AF of 4.26. The acquired DW images show minimal distortions even in the ponds, as can be seen in Fig. 1. Fig. 2a shows the color coded fractional anisotropy in a sagittal slice. The texture indicates the fiber orientation. The tensor data allows to resolve parts of the fine laminar medio-lateral oriented structures (red) in the ponds dividing ventro-dorsal oriented fibers (blue) into the Frontopontine tract (F), the Corticospinal tract (P) and the Temporoparietopontine fibers (PT). Using tensor based tractography, these fine detailed fiber tracts can be separated. Fig. 2b shows the medio-lateral fibers and some of the cortical fibers.

Conclusion: The combination of zoomed imaging with parallel imaging – ZOOPPA enables DWI acquisitions with 1 mm isotropic resolution at 7T. The high quality of the DTI data provides a high level of anatomical details.

References: [1] Griswold et al. MRM 1999;41:1236-45. [2] Heidemann, et al. HBM 2009 #254 F-PM. [3] Hwang, et al. JMR 1999;138:173-77. [4] Pfeuffer, et al. NeuroImage 2002;17:272-86. [5] Griswold, 2nd Workshop on Parallel Imaging 2004; p. 16-18.[6] Ivanov, et al. ISMRM 2009 #1547.
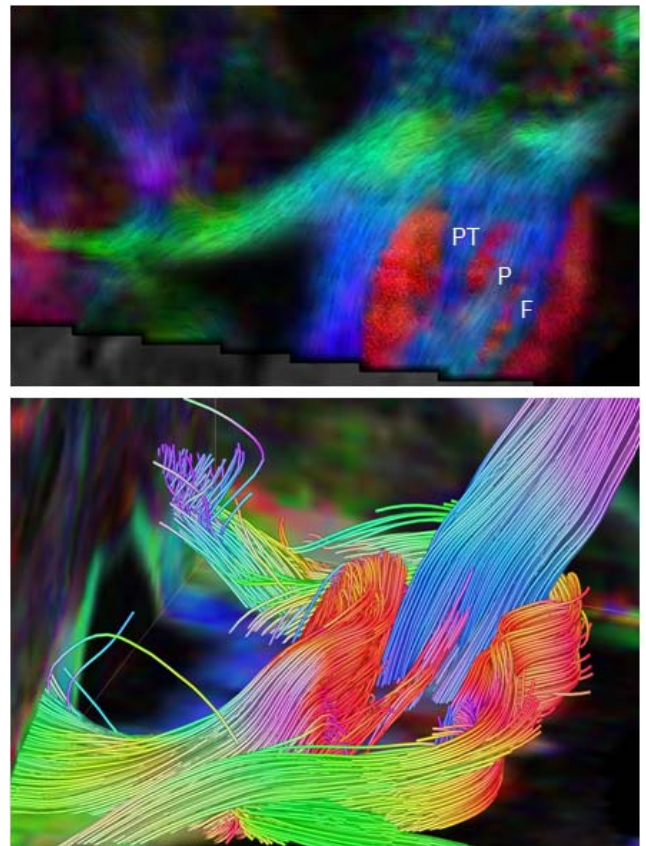
Fig 2: (top) The sagittal view of the texture diffusion results overlaid onto the anatomy allows identification of fine detailed fiber tracts. (bottom) Corresponding fiber tractography.