High Resolution Diffusion-Weighted Imaging Showing Radial Anisotropy in the Human Cortex In Vivo

R. M. Heidemann[1], A. Anwander[1], T. R. Knösche[1], T. Feiweier[2], F. Fasano[3,4], J. Pfeuffer[5], and R. Turner[1]

[1]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany, [2]Siemens Healthcare Sector, Erlangen, Germany, [3]Fondazione Santa Lucia, Rome, Italy, [4]Siemens Medical Solutions, Milano, Italy, [5]Siemens Medical Solutions, Charlestown, MA, United States

Introduction:

For high resolution diffusion weighted imaging (DWI) it is essential to use parallel imaging to reduce the effects of susceptibility induced geometric distortions as well as blurring due to T_2* decay [1]. However, parallel imaging is not without its limitations and even with large phased arrays it is still a challenge to obtain high acceleration factors greater than four in a single dimension. Recently the combination of a zoomed approach with parallel imaging was proposed to improve the image quality of single-shot EPI acquisitions [2]. In the current study we are using this approach to achieve high acceleration factors enabling high resolution DW imaging with single-shot EPI. With an in plane resolution of 1 mm it is possible to measure *in vivo* anisotropy in the gray matter of the human cortex. The visualized diffusion anisotropy orientated is normal to the folded cortical surface in all measured gyri.

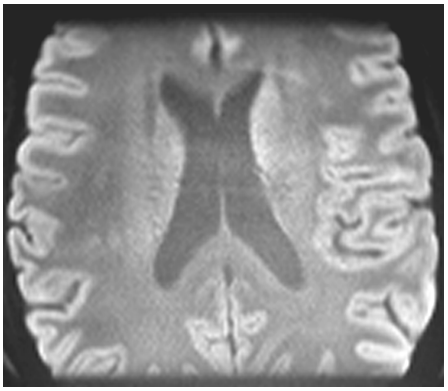

Fig 1: Single-shot zoomed DW EPI: This trace weighted image with b=1000 s/mm^2 was calculated from the tensor data.

Methods:

Experiments were performed on a 3T whole body MR scanner (Trio a TIM system) using a 32 channel phased array head coil (Siemens Healthcare Sector, Erlangen, Germany). Informed consent was obtained before each study. DW images were acquired with a monopolar Stejskal-Tanner sequence: TR = 4800 ms, TE = 68 ms, FOV = 150 mm, FOV phase = 74.7%, partial Fourier = 7/8, GRAPPA AF = 3, in plane resolution 1 x 1 mm^2, slice thickness = 3 mm, 30 slices with 50% gap, DW with b = 1000 s/mm^2, 6 directions and 22 averages. The total acquisition time was 12 min 45 s.

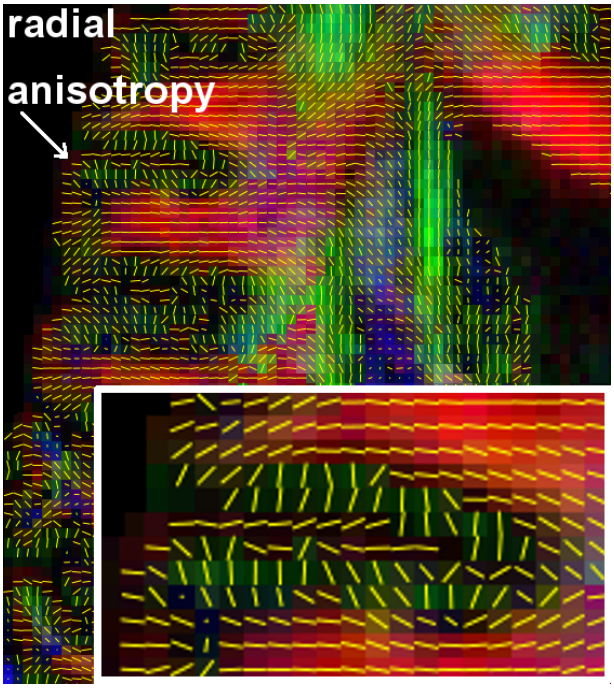

Fig 2: Axial slice of the principal diffusion directions overlaid on the color coded FA map. The inset shows the radial anisotropy in the cortex of the left inferior frontal gyrus.

Results and Discussion:

For the head geometry of the volunteer examined in this study a FOV of 220 mm would be necessary to avoid aliasing in phase encoding (PE) direction. With the zoomed approach using OVS we were able to reduce the FOV along PE by factor of two. This reduced FOV was further reduced by a factor of three due to the GRAPPA acceleration. In total this results in an acceleration factor of six This high acceleration factor allows us to shorten the echo time from 195 ms to 68 ms and to decrease the EPI readout from 242 ms to 29 ms. A single slice of the trace weighted image calculated from the tensor data with a b-value of 1000 s/mm^2 is shown in Fig. 1. The fractional anisotropy (FA) in the cortex was measured in the range of 0.05-0.2. The diffusion orientation was consistent in normal direction to the cortical surface on the crown of the gyri and in the sulci. The deep fundi did not show this clear radial direction. The main eigenvector of the diffusion data was visualized in an axial slice overlaid on the color coded FA weighted image in Fig. 2. Fig. 3 shows a top view on the brain with color coded FA values.

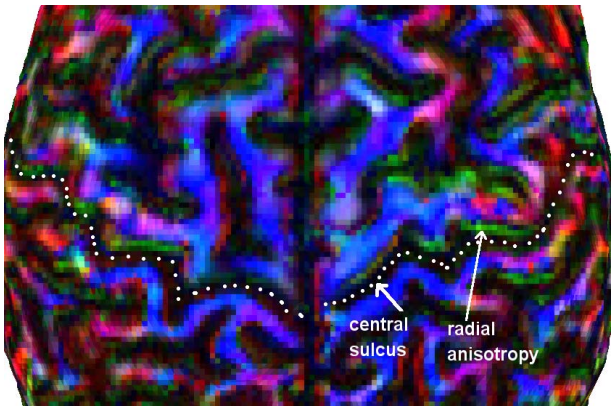

Fig 3: Top view on the brain with color coded FA values. The green stripe anterior to the central sulcus is the motor cortex with anterior-posterior anisotropy.

Conclusion:

In the current study high acceleration factors up to six have been achieved by combining a zoomed approach and parallel imaging. High acceleration factors are essential for high resolution DWI with minimal distortions. With the accomplished image quality, visualization and quantification of the radial anisotropy in the cortical mantle in living human subjects is possible. The cortex shows a consistent orientation of the principal diffusion direction and non-zero diffusion anisotropy.

References:

[1] Griswold et al. MRM 1999;41:1236-45. [2] Heidemann, et al. ISMRM 2008 #1284. [3] Griswold, MRM 2002;47:1202-10.