# High Resolution Single-Shot Diffusion Weighted Imaging with a Combination of Zoomed EPI and Parallel Imaging

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**Introduction:** Single-shot EPI is well established as the method of choice for diffusion-weighted imaging (DWI). However, the method is prone to artifacts due to off-resonance effects as well as blurring due to $T_2$* decay. It has been shown that the use of parallel imaging can significantly improve the image quality of single-shot EPI acquisitions [1]. Further improvements were achieved by combining a zoomed approach with parallel imaging [2]. In zoomed imaging aliasing artifacts can arise from imperfect outer-volume suppression (OVS), while in parallel imaging aliasing artifacts can arise from imperfect data reconstruction. The combination of both methods eliminates the weakness of each single technique. In the present study this combination is used to obtain high acceleration factors, enabling high resolution DWI.

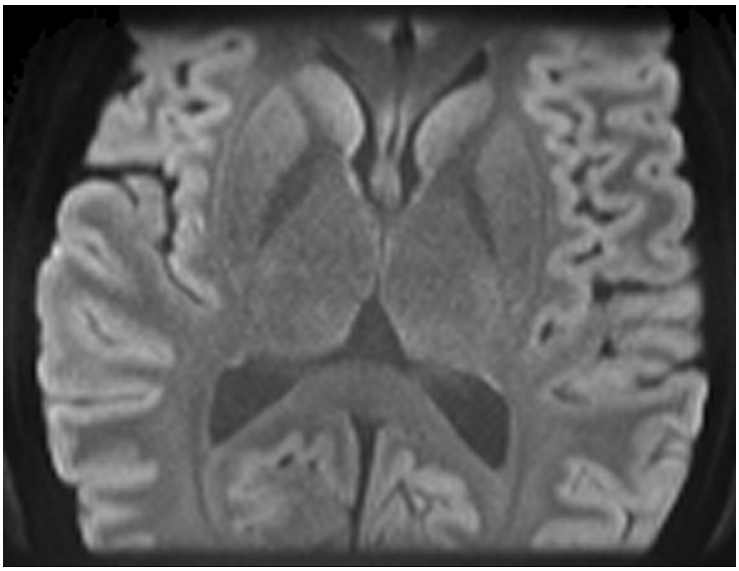

**Fig 1**: Single-shot zoomed DW EPI with 1mm in plane resolution: This trace weighted image with b=1000 s/mm$^2$ was calculated from the tensor data.

**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 with the following imaging parameters: 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, b = 1000 s/mm$^2$, 6 directions and 22 averages. The total acquisition time was 12 min 45 s.

**Results and Discussion:** Phase encoding (PE) direction was chosen AP to obtain less pronounced, symmetric distortions. For the head geometry of the volunteer examined in this study a FOV of 220 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 150 mm which was further decreased along PE direction to 74.7 % of the FOV in read-out (RO) direction. The resulting FOV in PE direction was 112 mm which corresponds to an acceleration factor of two. In addition GRAPPA with a 2D convolution kernel [3] and an acceleration factor of three was applied to the reduced FOV acquisition. This combination, OVS and GRAPPA, results in a total acceleration factor of six. With the presented protocol only 15% of k-space was acquired resulting in 23 k-space lines per image. Compared to a conventional protocol without parallel imaging and zoomed imaging the duration of the EPI readout is decreased from 242 ms to 29 ms while at the same time TE can be shortened from 195 ms to 68 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 acquired data can also be used for tractography as shown in Fig. 2. Using more than 6 diffusion directions rather than averaging could in principle increase the robustness of the tensor estimation. However, we opted for the SNR benefit that goes along with the shorter echo time of the 6 direction scheme.

**Conclusion:** Parallel imaging as well as zoomed methods can be used to accelerate the acquisition of DW images which allows for a reduction of echo time. This partially compensates the loss in SNR due to the reduced acquisition. Further, the reduced effective interecho spacing directly translates into reduced spatial distortions. Even though modern MR scanners are equipped with up to 32 independent receiver channels, it is still a challenge to achieve acceleration factors greater than four in a single direction. This is due to the fact that only a fraction of the receiver coils contribute to the parallel image reconstruction along a single direction. With the presented method it is possible to overcome this problem which is advantageous for high resolution DW imaging.

**References:** [1] Griswold, et al. MRM 1999;41:1236-45. [2] Heidemann, et al. ISMRM 2008 #1284. [3] Griswold, 2nd Workshop on Parallel Imaging 2004; p. 16-18.

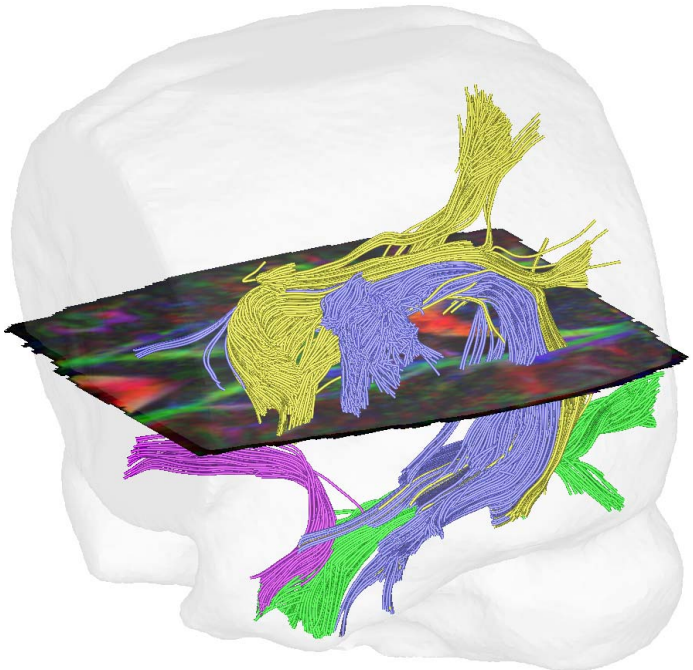

**Fig 2**: Tractography based on the single-shot zoomed EPI acquisition showing the reconstruction of inter-hemisphere association fiber bundles.