

# High-resolution diffusion kurtosis imaging (DKI) enabled by segmented position orientation adaptive smoothing (POAS)

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**Target Audience:** researchers and clinicians interested in Kurtosis imaging.

**Purpose:** Recent studies suggest that Diffusion Kurtosis Imaging (DKI) is more sensitive to brain microstructure than the well-known diffusion tensor imaging (DTI) [1, 2]; in particular, in gray matter where the diffusion profile is more complicated [3]. However, one drawback of DKI is that its estimation scheme is more poorly conditioned than DTI, because a 2<sup>nd</sup> and a 4<sup>th</sup> order tensor have to be estimated simultaneously [4]. Therefore, diffusion MRI data with different and higher b-values are required, which will result in a further reduced signal-to-noise ratio (SNR). As a consequence, high-resolution DKI with small voxel sizes has not been available *in-vivo* on clinical scanners. Here, we aimed to alleviate the low SNR issue of high-resolution DKI by using a novel version of the position orientation adaptive smoothing (POAS) [5], which is separately applied on grey and white matter segments.

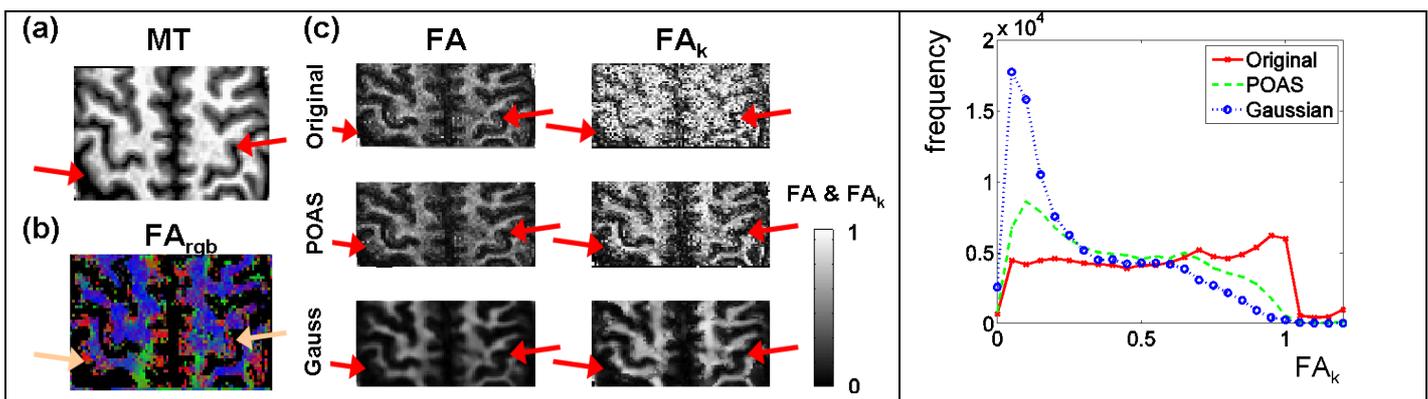
**Methods:** One healthy volunteer (male) was scanned on a MAGNETOM Trio, a Tim System 3T scanner (Siemens AG, Healthcare Sector, Erlangen, Germany). Diffusion weighted images were acquired using a reduced field-of-view (FoV) technique [6]: 161x58 mm FoV, 34 slices, 1.2mm isotropic resolution, and 1.3mm slice thickness. The FoV was positioned around the motor cortex (see Fig. 1a). The images were acquired at 3 different b-values: 21 at b=20 s/mm<sup>2</sup>, 100 at b=800 s/mm<sup>2</sup>, and 100 at b=2000 s/mm<sup>2</sup> using the directions suggested by [7]. The total scan time was ~25min. Before estimating the diffusion and kurtosis tensor, we corrected the data for eddy currents and motion artefacts [8] and performed different smoothing approaches: (a) none, (b) segmented POAS (max. full-width-at-half-maximum FWHM = 4mm), (c) Gaussian smoothing (FWHM = 2.4mm). Pre-processing was performed using the ACID SPM toolbox (<http://www.fil.ion.ucl.ac.uk/spm/ext/>) and POAS using the R-package dti (<http://cran.r-project.org/package=dti>). To estimate the diffusion and kurtosis tensor from the pre-processed images, we used the heuristic approach detailed in [4]. To assess the data quality for each smoothing method, we chose a well-known diffusion index map, the fractional anisotropy, for the diffusion (FA) and the kurtosis (FA<sub>k</sub>) tensor as suggested in [1]. Furthermore, we calculated the histogram of the FA<sub>k</sub> values within the brain.

**Results and Discussion:** Both smoothing methods evidently improved the data quality of FA and FA<sub>k</sub> maps (e.g. fewer ripples and noise, Fig. 1c). However, the conventional Gaussian smoothing method reduced the anisotropy in the gray matter drastically and thus obscured cortical structure, whereas POAS maintained the anisotropy information (Fig. 1c, arrows). POAS and Gaussian smoothing eliminated the number of artificially high FA<sub>k</sub> (>1), which are an indicator of poor data quality, almost entirely (Fig. 2). However, Gaussian smoothing biased the FA<sub>k</sub> values towards small values, since it mixes diffusion profiles from adjacent voxels (i.e. makes them equal), resulting in less anisotropic diffusion profiles [9]. POAS maintained the more realistic anisotropic diffusion profiles significantly better.

**Conclusion:** High-resolution DKI becomes possible on a clinical scanner if segmented POAS is used to enhance the SNR in the data.

**Acknowledgement:** This study was supported by the Wellcome Trust and Deutsche Forschungsgemeinschaft (DFG, MO 2397/1-1).

**References:** [1] Jensen et al., NMR Bio., 2010, [2] Hui et al., Stroke, '12, [3] Nagy et al., ISMRM, 2011, [4] Tabesh et al., MRM, 2011, [5] Becker et al., MIA, 2012, [6] Heidemann, MRM, 2010, [7] Caruyer et al., MICCAI, 2011, [8] Mohammadi et al., MRM, 2010, [9] Park et al., NI, 2004, [10] Helms et al., MRM, 2008.



**Fig. 1:** The effect of smoothing on FA and FA<sub>k</sub> maps. The anatomy is depicted in the (a) magnetization transfer (MT) [10], (b) the colour-coded FA map using POAS (red: l->r, green: a->p, blue: h->f). (c) FA and FA<sub>k</sub> maps based on the original (top), segmented POAS (middle), Gaussian smoothed data (bottom). The original data were noisy with ripple artefacts, which were reduced by smoothing. The arrows highlight regions in the gray matter, where the anisotropy information is lost after Gaussian smoothing. Colour coded FA was generated using the [DTI and Fibertools Software Package](#).

**Fig. 2:** Histogram of FA<sub>k</sub> for original (a), segmented POAS (b), Gaussian smoothed (c) data. In the original data artificial FA values occurred frequently (FA<sub>k</sub>>1 in Fig. 2a), which were almost eliminated with smoothing. Unlike POAS Gaussian smoothing biased the distribution of the FA values towards small FA<sub>k</sub>.