INVESTIGATION OF ARTIFICIAL INCREASE OF FRACTIONAL ANISOTROPY (FA) DUE TO TRUNCATION ARTIFACT IN DTI DATA AND COMPENSATION USING TOTAL VARIATION CONSTRAINED DATA EXTRAPOLATION

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Target audience: Researchers performing quantitative analysis on DTI data

Purpose: Signal truncation at the border of k-space results in image artifacts, known as Gibbs ringing. Especially images with high contrast in combination with low spatial resolution are prone to this artifact. This artifact strongly influences quantitative analysis as in Diffusion Tensor imaging (DTI). With DTI the signal of the un-weighted diffusion image(s) greatly influences the value of fractional anisotropy (FA) index calculated from the DTI data. An underestimated MR signal (lower than real value) without diffusion weighting leads to an overestimated FA value and vice versa (cf. Fig. 1 marked spots). The artifact in the un-weighted images can be reduced using k-space filtering with elliptic, exponential or Gaussian shape in order to reduce high frequency values. This however reduces the spatial resolution of the acquired data. A more sophisticated approach is the extrapolation of the k-space values with a total variation (TV) constraint [1]. The aim of our research was to investigate the extent of artifact reduction in FA maps if k-space extrapolation is applied to DT imaging data.

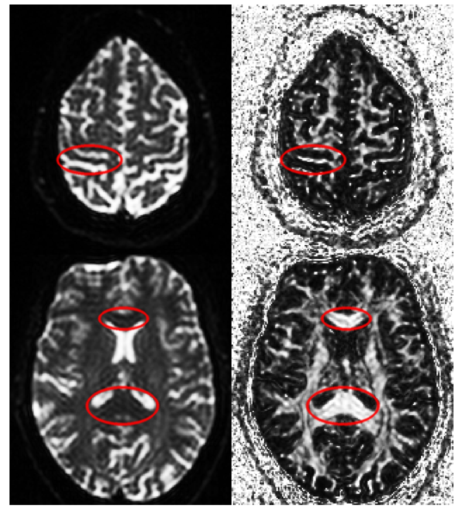

Fig. 1 Demonstration of truncation artifacts in b0 images and its impact on FA maps (overestimation).

Methods: DTI data were acquired at a 3T MRI (Tim Trio, Siemens Medical, Erlangen Germany) using a matrix size of 96x96 and a field of view of 240 mm (2.5x2.5 mm in plane resolution), 25 slices (2.5 mm thickness), 5 un-weighted images and 30 diffusion weighted directions. K-space data were derived directly from the scanner platform and imported into Matlab (The Mathworks, Nattick, MA, USA). The k-space data were zero-padded to a 192x192 matrix slice by slice. A freely available software code for sparse data recovery was used [2] and adapted to fill the zero-padded zones in k-space. In order to quantitatively compare FA values derived from filtered and unfiltered data, region of interest analysis was performed. ROIs were generated using Freesurfers white matter parcellation based on T1 weighted data. Additionally to the ROI information the distance of each voxel to the pial surface was determined, which allows to assess the change in FA due to filtering with respect to the distance of the voxel to the pial surface.

Results: Figure 2 show the results for four exemplary ROIs (left and right of pre- and post central gyri). The most important result is the average difference (red bar histograms) between FA values derived from unfiltered (uncorrected) and filtered (corrected) DTI data with respect to the distance to the pial surface. The difference shows a clear peak at 2.5 mm, which is exactly the acquired voxel size. For the precentral gyri ROIs (lower diagrams) one can also see the second peak at 7.5 mm. This shows that the artifact oscillates exactly with a period of two pixels (5 mm in the presented data).

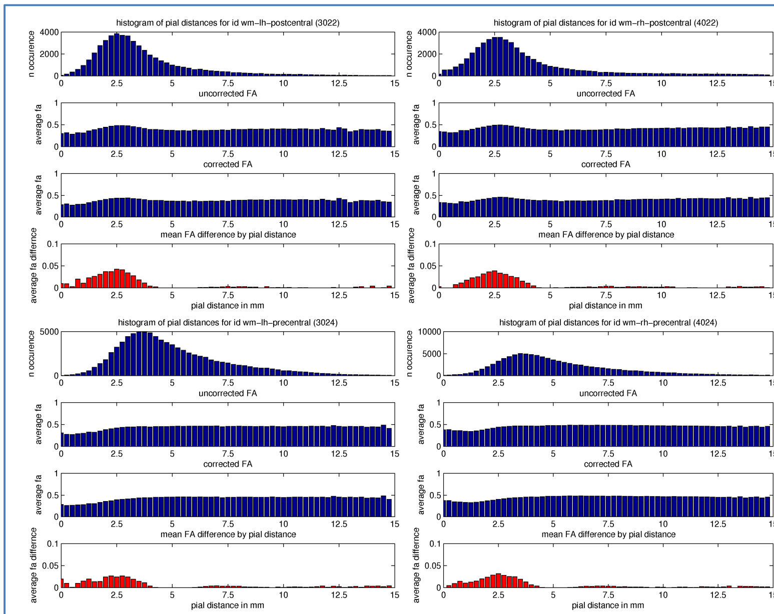

Fig 2. Results of ROI based analysis for four different white matter ROIs: wm-lh-postcentral (upper left), wm-rh-postcentral (upper-right), wm-lh-precentral (lower left), wm-rh-precentral (lower right). Each subfigure contains a histogram for distance to the pial surface, a plot for mean FA with respect to pial surface distance from unfiltered (uncorrected) and filtered (corrected) data, as well as a diagram showing the mean difference between both datasets with respect to pial distance.

Discussion: The presented analysis showed that Gibbs ringing introduces an artificial increase in FA with a clear correlation to the pial surface distance. The increase of FA was corrected using filtered DTI data with k-space TV-extrapolation. Since the artificial increase of FA due to truncation artifact is always largest if the distance to the pial surface meets the voxel size, different shapes (e.g. different gyri thickness between subjects) of the same anatomical brain structure will lead to different FA profiles. This adds a bias to the FA data, which solely depends on the anatomical shape, which in turn might lead to false positive correlation in group analysis.

Conclusion: To the best of our knowledge, this is the first detailed analysis, which demonstrated the effect of Gibbs ringing (truncation artifact) in the analysis of fractional anisotropy determined from DTI data. Pre processing of the un-weighted data using k-space extrapolation with total variation constraint can decrease this systematic bias.

References: **[1]** Block, K. T., Uecker, M., & Frahm, J. (2008). Suppression of MRI truncation artifacts using total variation constrained data extrapolation. *Int J Biomed Imag*, *2008* **[2]** Becker, S., Bobin, J., & Candès, E. J. (2011). NESTA: A Fast and Accurate First-Order Method for Sparse Recovery. *SIAM Journal on Imaging Sciences*, *4*(1), 1–39.