Effect of using super-resolution technique in slice direction on DTI fiber tractography

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Introduction: In 2D multislice Diffusion MRI, the resolution in the slice-select direction is often lower than the in-plane resolution. For application of fiber tractography, isotropic resolution is recommended, although true 3D acquisition methods are not practical. However, if the imaging volume is acquired twice with small spatial shifts between acquisitions or with slice overlap, combination of these data sets result in improved resolution in the slice-select direction. In this study we employed this approach to diffusion tensor data acquisition and evaluated its effect on fiber tractography.

Material and Methods: 6 DTI datasets with slice distances of 100% down to 50% (in steps of 10%) of the slice thickness were acquired from a healthy volunteer. Slices were oriented axially and covered the whole brain. An in-plane resolution of 2.2 x 2.2 mm² was used, which was interpolated to 1.1 x 1.1 mm² by zero filling. Each data set comprised 5 b_0 images and 30 diffusion weighted images (direction scheme Jones30 [1]) with a b-value of 1000 s/mm². The final datasets had an effective slice thickness of 2.2 mm (50 #slices), 1.98 mm (60 #slices), 1.76 mm (70 # slices), 1.54 mm (80 #slices), 1.32 mm (90 #slices) and 1.1 mm (100 #slices). The slice excitation order was interleaved. DTI post processing and fiber tractography was performed using Diffusion Toolkit (DTK) [2]. In order to select equal fiber bundles for comparison, ROIs were drawn into a high resolution anatomical dataset (MP-RAGE, 1 mm³ isotropic resolution) according to [3] and realigned to the individual DTI datasets using affine transformation.

Results: The resolution enhancement in slice direction is clearly visible, as shown in Fig. 1 (FA map in the background). Especially thin white matter structures, which are oriented almost parallel with respect to the slice orientation, such as the cingulum, were found to be reproduced distinctly sharper with decreasing effective slice thickness (cf. Fig. 1 left to right). In particular, we observed an improved representation of the cingulum bundle (Fig. 1 upper row) as an example structure, which clearly benefits from this interpolation approach. However, the improvement may not appear as obvious as expected, as seen from Fig. 1, when comparing the different resolution steps. Some structures do not necessarily benefit from super-resolution in slice-select direction as exemplified with the left cingulum in the hippocampal part (Fig. 1, upper row). In addition, acquisition times increase linearly with increasing slice overlap due to the reduced brain coverage, which, in turn, has to be compensated by acquiring more slices.

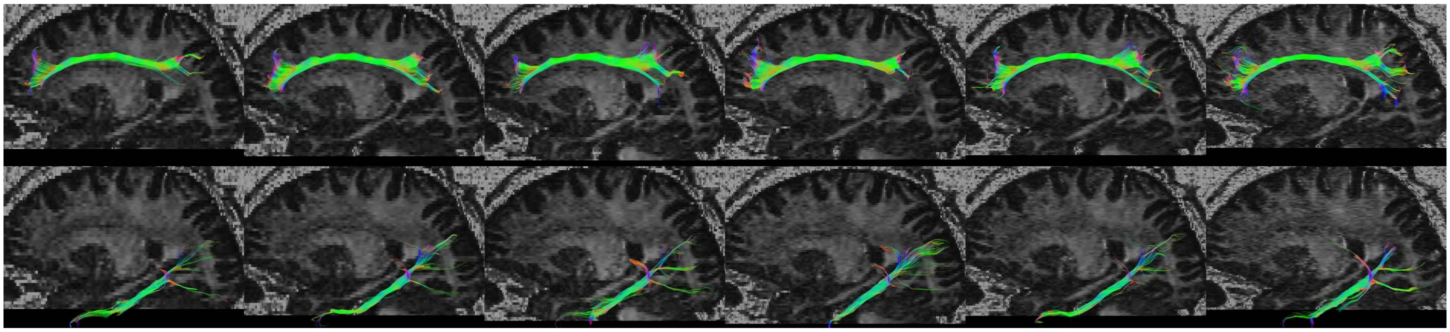

Fig. 1 Visualization of two selected fiber bundles (left cingulum – *top row*, left cingulum in the hippocampal part – *bottom row*) for different data sets with effective slice thickness of 2.2, 1.98, 1.76, 1.54, 1.32 and 1.1 mm, respectively (from *left* to *right*). The sagittal plane in the background shows the corresponding FA maps and visualizes the resolution improvement in slice direction (*inferior-superior*).

Discussion: We found that the super-resolution method applied in slice direction improves diffusion property maps and fiber tractography. The main advantage of super resolution is that the total acquisition time scales linearly with the resolution improvement. Further improvements can be achieved by using iterative back projection (IPB) algorithms [4], which take into account the Gaussian slice excitation profile. As shown more recently, super-resolution imaging can also be applied by using spatial modulation of magnetization (SPAMM) [5].

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