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Improved Spatial Regression Analysis of Diffusion Tensor Imaging for Lesion Detection during Longitudinal Progression of Neurodegenerative Disease in Individual Subjects

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Abstract

Diffusion tensor Imaging (DTI) enables accurate description of the degree and direction of water dynamics in biological tissues, which provides detailed information about white matter microstructure, and has been widely used in the field of neuroscience and medicine. However, DTI is susceptible to numerous detrimental artifacts that may impair the reliability and validity of the obtained data. Image quality of DTI is therefore critical. In Chapter 3, the effectiveness of three popular QC tools including DTI studio, DTIprep and TORTOISE are quantitatively compared. Both synthetic and *in vivo* human brain data were used to quantify adverse effects of major DTI artifacts to tensor calculation as well as the effectiveness of different QC tools in identifying and correcting these artifacts. The technical basis of each tool was studied; the different functions and I/O formats that three QC tools provide were also discussed.

Subject-specific longitudinal DTI study is vital in the investigation of pathological changes of lesions and disease evolution, which remains an important area of current research. Spatial REgression Analysis of Diffusion tensor imaging (SPREAD) is a nonparametric statistical method that combines spatial regression and permutation techniques to achieve effective detection of localized longitudinal changes within the whole brain at individual-level without a priori hypotheses.

In Chapter 4, we propose an improved SPREAD (iSPREAD) method. A three-dimensional nonlinear anisotropic diffusion filtering method is incorporated in iSPREAD to eliminate the potential shortcomings caused by the Gaussian kernel used in the SPREAD method. Results from both simulated and *in vivo* human brain data demonstrated that iSPREAD identifies subject-specific longitudinal changes in the brain with substantially improved sensitivity, accuracy, and enhanced statistical power.

As an extension of iSPREAD; we present a general statistical method that facilitates analysis of serial DTI studies for testing regionally specific changes in Chapter 5. Two types of voxel-level test statistics were estimated and used to test against the null hypothesis among groups of DTI data across time. The proposed statistical framework is shown to be accurate and can be applied to a broad spectrum of longitudinal studies to help detect localized changes at individual-level with carefully designed test statistics.