DW-MRI B-tensor encoding acquisition and processing on a pre-clinical Bruker scanner.

Introduction

Diffusion-weighted MRI (DW-MRI) is a technique capable of characterizing microstructural properties in tissue[1]. While the technique has shown high sensitivity, standard approaches lack specificity to certain microstructural properties that can be important in neurodegeneration events[2].

Advanced DW-MRI acquisition schemes are able to provide additional information about tissue microenvironment[3]. Diffusion gradient waveforms with complex shapes[4] measure q-space trajectories, rather than a single point in q-space, and are summarized by a B-tensor[5] (a generalization of the b-value and b-vector). Different measurements using different B-tensors (size, shape, and orientation) enable DW-MRI to assess microstructural details that are otherwise inaccessible to the classic pulse-shaped diffusion gradient acquisition[6].

Because B-tensor encoding schemes are an active topic of investigation, these sequences are not readily available in MRI systems. Still, the DW-MRI community has developed a series of resources and tools that enable researchers to implement B-tensor encoding. In this work, we present an acquisition and processing pipeline that we implemented for our preclinical Bruker system, highlighting the different open source tools used.

Objectives

Share the pipeline that we implemented for diffusion weighted B-tensor encoding acquisitions on a preclinical 7 T Bruker scanner using free software shared by the DW-MRI community. We also present an auxiliary free repository that contains helpful tools that facilitate the implementation.

Methods

Figure 1 shows a flowchart for an acquisition and analysis pipeline for b-tensor encoding images on a preclinical Bruker system. We briefly describe each step in the following subsections.

Waveform design for B-tensor encoding

The NOW toolbox (Numerical Optimization of gradient Waveforms)[7], available in https://github.com/jsjol/NOW is a MATLAB package that optimizes gradient waveforms to acquire B-tensor encoding images. This toolbox optimizes the waveform to a specific B-tensor shape but limits it to specified valid hardware parameters of the MRI scanner to be used. The most recent version also features compensation for concomitant gradients[8] and motion[9].

Free-gradient waveform sequence in a Bruker scanner

The "MCW sequences" available on the Preclinical Neuro MRI repository https://osf.io/ngu4a/ can be used to obtain B-tensor encoding images. These sequences can acquire DW-MRI using free diffusion gradient waveforms (such as the ones obtained through NOW) on Bruker systems with Paravision 6.0.1 software. Installation and use of these sequences are documented in the corresponding manual; familiarity with Paravision is required.

Processing of B-tensor images

Processing of B-tensor encoded images is an active field of investigation. The freely-available Multidimensional diffusion MRI Matlab toolbox (https://github.com/markus-nilsson/md-dmri)[10] is able to perform various forms of analysis on B-tensor DWI.

The MDE_auxTools repository

We provide useful functions that aid in the implementation of B-tensor encoding sequences on a Bruker scanner (https://github.com/RicardoRios46/MDE_auxTools). These functions are intended to be used as connectors between tools developed by the DW-MRI scientific community such that complete acquisition pipelines can be built (Figure 1).

Results

We implemented the pipeline in Figure 1 on a 7 T Bruker system to obtain B-tensor encoded DWI of *ex vivo* rat brains using a Cryoprobe. Figure 2 shows q-space trajectory Imaging (QTI)[5] metrics computed with the MD-MRI toolbox.

Conclusion

In this work, we show an implementation of B-tensor encoded DW-MRI acquisition on a pre-clinical Bruker scanner and their subsequent analysis. We highlight the different software and steps needed for the implementation and a complementary toolbox to facilitate this process. Other institutions interested can do a similar approach with the presented pipeline.

References

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Figures

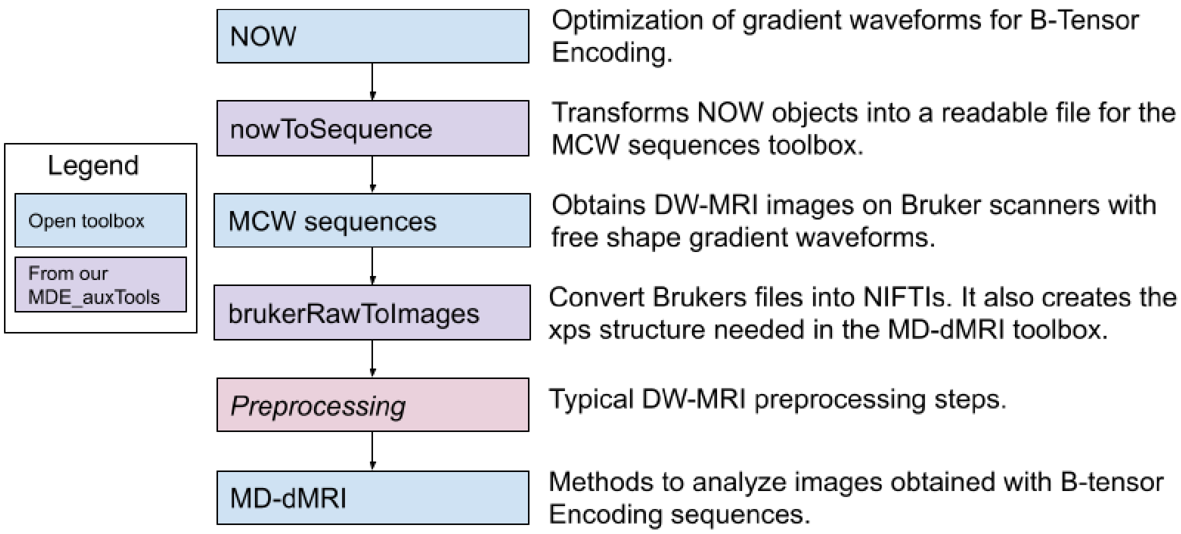
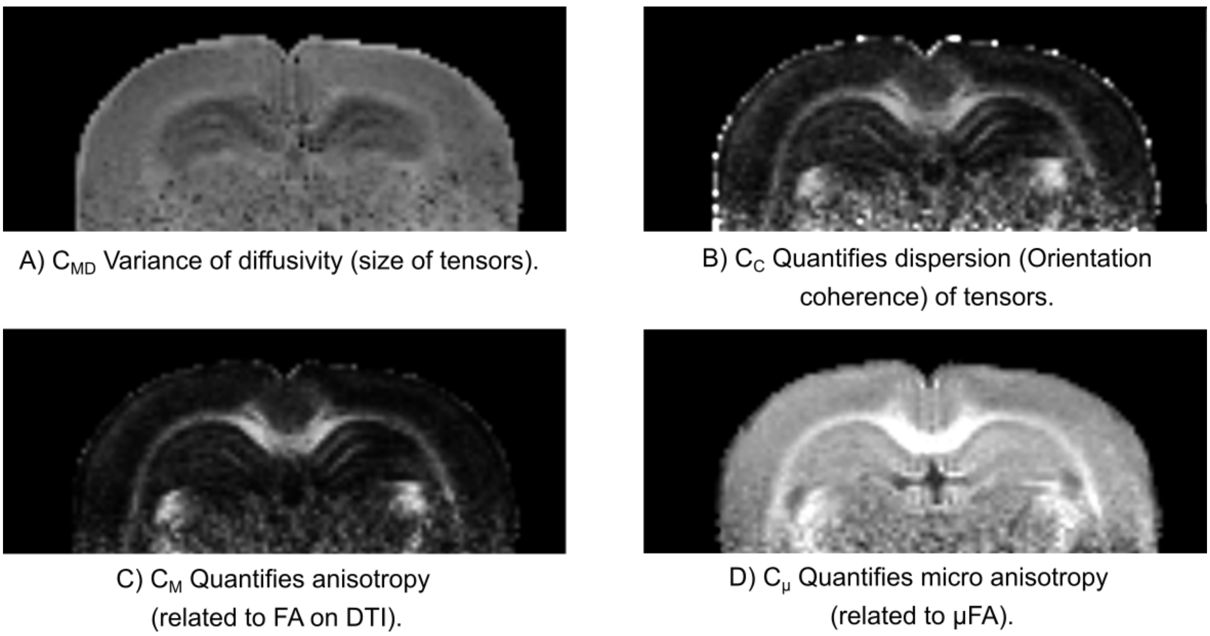


Figure 1. A complete pipeline to acquire DW-MRI B-tensor encoding images. We use open software developed by the DW-MRI community. MDE_auxTools contains useful functions that serve as connectors between different steps in the pipeline.



A) C_{MD} Variance of diffusivity (size of tensors).

B) C_C Quantifies dispersion (Orientation coherence) of tensors.

C) C_M Quantifies anisotropy (related to FA on DTI).

D) C_μ Quantifies micro anisotropy (related to μFA).

Figure 2. Quantitative maps of metrics obtained with Q-space Trajectory Imaging (a B-tensor encoding processing analysis) using the pipeline.