Title: Neurite Orientation Dispersion and Density Imaging at 9.4 Tesla

Trainee Name: Patrick McCunn

Supervisor(s): Dr. Robert Bartha

Structured Abstract:

Diffusion weighted magnetic resonance imaging (dMRI) is a powerful MRI technique that provides a wealth of information regarding tissue microstructure, from which structural connectivity and pathological changes within the brain can be inferred. Recent advancements in dMRI have focused largely on strategies to apply geometric models of tissue microstructure to model the diffusion signal. Neurite orientation dispersion and density imaging (NODDI) is one such technique, where the total diffusion signal is modelled as the sum of the individual contributions from three non-exchanging compartments: intra-neurite water fraction (NDI), extra-neurite water fraction (1-NDI) and cerebral spinal fluid volume fraction (IsoVF). Further, orientation dispersion index (ODI) characterizes the angular variation and spatial configuration of neurite structures. Such indices may provide more specific markers of brain tissue architecture than standard dMRI measures, such as mean diffusivity (MD) and fractional anisotropy (FA), as they directly model the relevant microstructural regions.

Previous work has shown NODDI to be a promising technique in humans at clinical field strength (Zhang et al 2012). As ultra-high field MRI, and specifically pre-clinical rodent MRI, faces many unique challenges, it is important to carefully define reliability and reproducibility in the context of rodent imaging at 9.4 Tesla. In recent work, our lab demonstrated that ODI and NDI are highly reproducible and reliable both between and within subjects. Furthermore, we observed that small biological changes (< 5%) may be detected with feasible sample sizes (n < 6-10). In contrast, IsoVF was observed to have low reliability and reproducibility, requiring very large sample sizes (n > 50) for biological changes to be detected.

As NDI and ODI are both highly relevant metrics in the context of neural injury, we have begun to apply NODDI to pre-clinical models of concussion. Previous work using diffusion tensor imaging (DTI) has shown changes in multiple diffusion metrics well after clinical assessment scores return to normal. Unfortunately, the measured changes in these metrics have been inconsistent across studies and it is important to study them further in pre-clinical models to determine their accuracy and suitability for translation to diagnostic medicine. We aim to apply NODDI to a closed-skull traumatic brain injury model in rats and hypothesize that the metrics NDI and ODI will be able to detect subtle microstructural changes and correlate closely with subsequent histological analysis. Data collection and analysis is ongoing.

In conclusion, we believe the application of NODDI to pre-clinical models of neuronal injury will allow highly specific quantification of in-vivo brain tissue microstructure in pre-clincial rodent models.