Diffusion Tensor Imaging as a diagnostic tool to assess partial nerve laceration severity and recovery in a rat model ex vivo

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Introduction

- Our previous studies have demonstrated that MRI/ DTI, can differentiate between crush and complete transection peripheral nerve injuries in a rat model.
- DTI measures the directionally-dependent effect of barriers on the random diffusion of water.
- In ordered tissues such as nerves, this data can be used to reconstruct fiber tracts displaying axonal continuity after nerve injury and surgical repair.
- We evaluated DTI to assess nerve regeneration following graded partial transections with surgical repair in the rat sciatic nerve injury model.
- The long-term goal is to validate the MRI findings against histology.

Methods

- Sprague-Dawley rats
- Partial nerve transection (25, 50, and 75%) via graded device (Figure 1).
- Endpoints at 4 and 12 weeks post recovery.
- Nerves harvested, fixed, and scanned with a 7 Tesla MRI
- Histological (Toluidine blue staining) assessments of 500nm sections were performed for validation.

Figure 1

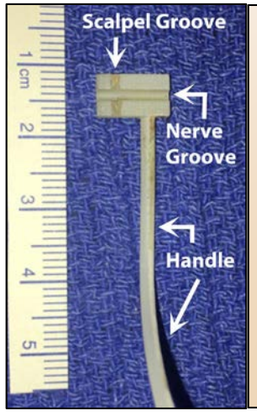

Figure 1: Partial cut device with nerve and scalpel grooves. Different devices were used for each of the three different cut depths.

Results

- MRI/ DTI was able to recognize the degree of injury and recovery
- This correlated with histological evaluations at 4 and 12 weeks.
- There is an inverse relationship between fiber length and cut-depth, along with reduced fiber coherence, FA, and MD within the injury site (Figure 2).
- Violin plots of MRI data separated 4 and 12 weeks, indicating the evolution of each distribution during the recovery process (Figure 3).
- Histologic analysis confirms the DTI analysis. Figure 4 displays representative images of all 3 groups at 4 and 12 weeks.

Figure 2

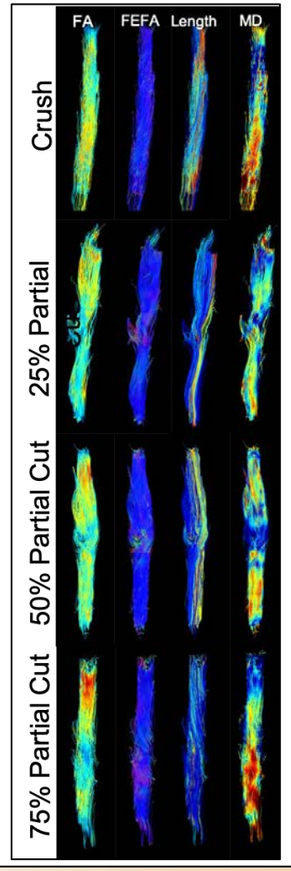

Figure 2: Representative tractography from crush and partial nerve transections. Color-coded tracks of fractional anisotropy (FA), FEFA (V1*FA), track length and median diffusivity (MD) are shown.

Figure 3

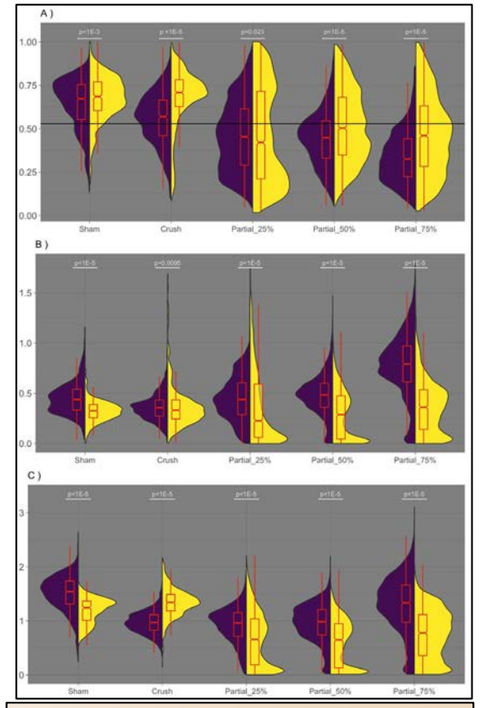

Figure 3: Split violin plots of FA (top), radial diffusivity (RD - middle) and axial diffusivity (AD – bottom) for sham, crush, and partial transections at 4 (purple) and 12 (yellow) weeks. Boxplots are in red with the p-values for Wilcoxon rank-sum tests for 4 vs 12 weeks. Note that recovery appears to be heterogeneous in sham and crush injuries, while partial transections show broad distributions.

Figure 4

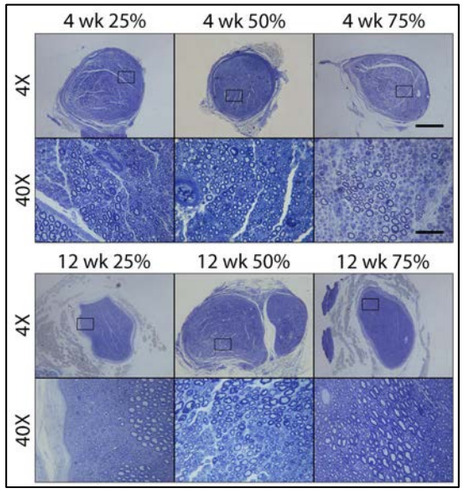

Figure 4: Histology images of partial transections distal to the injury site. Black boxes in 4X images mark the location of the 40X images. Scale bars: 4X = 500um, 40X = 50um.

Conclusions

- These results indicate that high-resolution DTI of *ex vivo* rat sciatic nerve yields viable biomarkers of peripheral nerve recovery following partial transection and surgical repair.
- Future work includes longitudinal *in vivo* measurements of transected nerves.