Clinically Feasible Microstructural MRI to Assess Tissue Injury in the Cervical Spinal Cord: Normative Data, Variations with Confounding Variables, and Reliability

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Introduction

Diffusion tensor imaging (DTI), magnetization transfer (MT), and T2*-weighted imaging (T2*w) quantify aspects of spinal cord microstructure. This study aimed to create a clinically relevant protocol employing these techniques and report normative data, variations with confounding variables, and test-retest reliability, to determine if these techniques are ready for translational studies.

Methods

32 healthy subjects underwent DTI, MT, and T2*w imaging at 3T in <20 minutes, using standard pulse sequences and spine coil. Data were automatically analyzed with Spinal Cord Toolbox (SCT). Data were extracted from spinal cord (SC), white matter (WM), grey matter (GM), and 30 individual WM tracts, including DTI metrics fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD), MT ratio (MTR), and T2*w WM/GM ratio (grey-white contrast). Cross-sectional area (CSA) was calculated for SC, WM, GM, and each WM funiculus. Test-retest coefficient of variation (TR-COV) measured reliability in 15 DTI, 13 MT, and 10 T2*w datasets.

Results

Metrics differed between WM and GM ($p<0.05$) for AD, FA, RD, and MTR, and between individual WM tracts (ANOVA $p<0.05$) for FA, MD, RD, and T2*-WM/GM. Several relationships exist between metrics and subject characteristics (e.g. FA ~ age, $r=-0.37$, $p=0.05$) and between different metrics (e.g. FA ~ RD, $r=-0.76$, $p<0.0001$). All metrics varied by rostro-caudal level (ANOVA $p<0.05$) except AD, and most showed monotonic variations except T2*-WM/GM, GM CSA, and VC CSA. Reliability was high for all metrics extracted from SC, WM, GM, and key WM tracts (lateral corticospinal, gracilis, cuneatus, spinothalamic) (TR-COV=0.9-6.9%), with the exception of RD (TR-COV=3.6-14.2%). CSA measures were also highly reliable (TR-COV=1.1-4.9%) except in the ventral columns (TR-COV=8.4%).

Conclusions

Reliable quantitative assessment of SC microstructure is clinically feasible. Important variations exist with age, sex, and rostro-caudal level. The results pave the way for clinical studies, with potential for improving diagnostics, developing biomarkers, and predicting outcomes.

Learning Objectives

By the conclusion of this session, participants should be able to: 1) gain an understanding of microstructural MRI techniques, 2) appreciate the potential clinical uses of microstructural MRI of the cervical spinal cord, and 3) realize that a simplified protocol using these techniques is ready for clinical studies.