Trends and differences in DTI metrics across ages and spinal cord levels in normal children

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Introduction: Diffusion tensor imaging (DTI) of the spinal cord is recently shown to be feasible and could be of diagnostic value in diseases affecting the spinal cord. The majority of these studies are undergone in adults and focus on cervical spinal cord with limited comparison to normal cervical and thoracic spinal cord data. The goals of this study were 1) to evaluate the age-dependent evolution of the ADC and FA values of the normal pediatric cervical and upper thoracic cord, 2) to evaluate differences of the ADC and FA values between genders, 3) to evaluate whether there are differences of ADC and FA values between upper cervical (UC; C1-C4), lower cervical (LC; C4-C7) and upper thoracic (LT; T1-T4) levels, and 4) to evaluate relationship between DTI scalar metrics and orthograde maturation of the spinal cord.

Material and methods: A total of 56 children aged <18 years with normal MRI studies of spinal cords, and without a history of spinal cord injury or systemic central nervous disease, were retrospectively reviewed. The DTI sequences of the spinal cord obtained from 1.5Tesla MR scanner (Magnetom, Avanto, Siemens Health Care, Germany) were post processed using SyngoDTI software to reconstruct the DWI, ADC, FA and color-coded FA maps. Automatic three-dimensional regions of interest (ROI) were manually placed at the center of the cervical and upper thoracic cord at each vertebral level on a sagittal image. The ADC and FA values including the standard deviation (SD) were recorded and used to evaluate their relationship with age, gender and differences between three spinal levels (UC, LC, UT). A total of 23 subjects were categorized in 0-3years group and 33 subjects were in >3 years of age group assuming orthograde maturation of the spinal cord would be completed after 3 years of age.

Results: The 56 pediatric subjects (26 males and 30 females) range in age from 2 months-17 years with a mean age of 68.5 months (SD 59.1 months). FA and ADC show statistically significant relationships with age for most of the twelve ROIs, increasing and decreasing, respectively, but do not show difference in relationships between genders. For ADC, a comparison of means between the three levels show statistically differences between the ROIs in the UC (989 $10^{-6}$mm$^3$/sec) and UT (885 $10^{-6}$mm$^3$/sec) [p < 0.001], and between the LC (954 $10^{-6}$mm$^3$/sec) and UT (885 $10^{-6}$mm$^3$/sec) [p =0.001]. No differences were found between the levels for FA, ADC values in UT in >3 years are significantly smaller than UT in 0-3 years and also smaller than UC and LC in >3 years. FA values for each level in >3 years are significantly larger than that level in 0-3 years (Figure 1,2).

Discussion: Our study considered a relatively large number of normative data from cervical and upper thoracic spinal cord of neonates, infants, young children and adolescents. We showed that with increasing age (from neonatal period to adolescence), ADC values have a significantly decreasing trend while the FA values have a significantly increasing trend within the cervical and upper thoracic spinal cord. The age related evolution of DTI metrics in the pediatric spinal cord is similar to DTI metrics in the pediatric brain representing the progressive development and maturation of the central nervous system. Our normative data will serve as an age-matched control group to quantify the changes in various childhood diseases affecting the spinal cord. We also showed that there are differences in ADC means between UC, LC and UT in decreasing order across the age groups; therefore matching both the age and the spinal cord levels in comparing ADC values between normal and abnormal spinal cord is important in children. The normal maturation of the spinal cord is known to advance cranio-caudally and the myelination of the white matter tracts is expected to be complete at the end of 2 years of age. The differences in ADC means between upper and lower cervical cord and upper thoracic cord shown in our study in children younger and older than 3 years of age need to be further investigated.

Figure 1
Figure 2

Comparison of ADC by Spinal Cord Level and Age

Comparison of FA by Spinal Cord Level and Age

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