White Matter Maturation in Older Children Demonstrated with Diffusion Tensor MRI

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Purpose
To characterize the changes in water diffusion during development of the centrum semiovale in children and adolescents, using diffusion tensor MR imaging (DTI).

Introduction
White matter maturation in the human brain continues from birth through adulthood, with myelination playing a large role in this developmental process. Diffusion tensor imaging of white matter in newborns (1) shows a greater water isotropic diffusion coefficient (Dbar) with less diffusion anisotropy (Aσ21), than in the adult brain (2). The time course of these developmental changes of Dbar and Aσ21 in the central white matter tracts of the corpus callosum and the internal capsule shows that they reach adult values after 6 years of age (3). In this study, we examine water diffusion throughout childhood and adolescence in the later-maturing, more peripheral white matter of the centrum semiovale.

Methods
Retrospective analysis was performed on normal MR examinations in 91 subjects (ages 2 years to 17 years) referred to St. Louis Children’s Hospital for clinical neuroimaging. Patients with a known organic brain disorder, with neurological manifestations of a systemic disorder, or with specific clinical evidence of neurological dysfunction, were excluded from this series. Each study included diffusion imaging with full tensor encoding.

At the level of the centrum semiovale, the gray/white junction was determined by threshold-based automatic segmentation of the Aσ21 image. Overlaying this contour on the T2-weighted images confirmed proper placement. Dbar and Aσ21 (1,2) were measured from white matter contained within the contour. ROI data were pooled into 5 groups, each encompassing an age range of 3 years. The mean of each group, with 95% confidence intervals, was computed.

Results
Figure 1 shows the relationship between Aσ21 and age for children and adolescents. A statistically significant increase in the anisotropy of the centrum semiovale is noted until ages 8-11. Figure 2 shows a statistically significant decrease in Dbar of the centrum semiovale over the same age range. These trends in Aσ21 and Dbar continue through the second decade of life; however, the changes after age 11 do not achieve significance at the 95% confidence level. Figure 3 contrasts anisotropy in the centrum semiovale of a 4 year old and a 16 year old.

Discussion
Overall, the most dramatic changes in water diffusion during brain development take place before the age of 2 years. However, it is clear that brain maturation, as assessed with DTI, continues well beyond the first 2 years of life (4). In the internal capsule and corpus callosum, Dbar and Aσ21 appear to reach adult values at approximately age 6 years (3). In the present study, Dbar and Aσ21 measured in the more peripheral white matter of the centrum semiovale begin to asymptote (level off) later in childhood – at the age of 8 to 11 years.

Conclusion
DTI is sensitive to white matter maturation in later childhood and adolescence. The isotropic diffusion coefficient and the diffusion anisotropy of the centrum semiovale both reach adult values at a later age than in more central white matter tracts, reflecting more prolonged white matter development in the centrum semiovale.

References