Diffusion Tensor Imaging of remaining brain after long term hemispherectomy

A. V. Faria[1,2], J. Choi[1], E. P. Vining[1], J. Zhang[1], K. Oishi[1], X. Li[3], H. Jiang[1], K. Akhter[1], P. van Zijl[1,3], M. I. Miller[4], A. Bastian[1,3], and S. Mori[1]

[1]Johns Hopkins Medical Institutes, Baltimore, MD, United States, [2]State University of Campinas, Campinas, SP, Brazil, [3]Kennedy Krieger Institute, Baltimore, MD, United States, [4]Center for Imaging Studies, Johns Hopkins Medical Institutes, Baltimore, MD, United States

***INTRODUCTION*:** The human white matter consist of three types of axonal tracts: the association (cortico-cortical), projection (cortical - subcortical), and commissural (right-left) tracts. These tracts tend to be segregated in the deep white matter areas but are intermingled in the peripheral (close to the cortex) areas. Diffusion tensor imaging (DTI) is capable of delineating the macroscopic architectures of the white matter, although it has severe limitations in deciphering the complicated axonal trajectories in the peripheral white matter regions. For human white matter connectivity studies, secondary (Wallerian) degeneration after brain lesions has been a major problem. In this study, we investigated the white matter architecture of hemispherectomy patients using DTI. Our hypothesis is removal of the commissural tracts should cause: 1) severe secondary degeneration in the ipsilateral projection and contralateral commissural fibers, and 2) simplification of the white matter structures contralateral to the hemispherectomy.

***METHODS*:** 11 post- hemispherectomy patients (8 with right hemispherectomy) and 11 healthy controls paired by age and gender were included in this study. The previous conditions that clinically indicated the hemispherectomy were intractable seizures by stroke, dysplasia or Rasmussen encephalitis. Patients' ages ranged from 1.75 to 13.6 years-old at surgery (mean 6.3) and they were scanned between 2 and 18 years after surgery (mean 9.5). Images were acquired using a 1.5T scanner with b=700s/mm^2. After skull strip, we segmented the brain taking off the remaining parts of the removed hemisphere. Nonlinear transformations between each subject's data and a single subject atlas (that also had one hemisphere removed, the same as in the subject) were obtained using fractional anisotropy (FA) and b0 based (dual contrast) Large Deformation Diffeomorphic Metric Mapping (LDDMM). The atlas contains detailed parcellation of 176 white and gray matter structures. By warping our atlas to each subject original space we measured size, FA, apparent coefficient diffusion (ADC), parallel diffusivity ($\lambda_{||}$, the primary eigenvalue) and perpendicular diffusivity ($\lambda\perp$, the average of the secondary and tertiary eigenvalues). This approach is called atlas-based analysis (ABA) hereafter. The same parameters were also analyzed by a voxel-based analysis (VBA). In this case, we used the Jacobian determinants of the LDDMM matrix to access differences in brain sizes. Wilcoxon Rank Sum test was carried out to access differences between groups (p value < 0.05) after correction for multiple comparisons by false discovery ratio.

RESULTS and DISCUSSION: Figure 1 and 2 show the results of the VBA. The overall anatomical changes detected by the VBA analysis agreed with visual evaluation, such as increased extra-cerebral spaces and decreased sizes of the ipsilateral cortico-spinal tract (CST) and the cerebral peduncle and the contralateral corpus callosum (CC) and cerebellar peduncles (Figure 1). These size changes were also accompanied by decreased FA and increased T2 and ADC (Figure 2) in the CST and the CC, but not always in the other areas with the size reduction. Interestingly, FA of the ascending sensory tracts (the medial lemniscii) is not significantly affected. If abnormality occurs along individual tracts, the ABA approach may provide higher sensitivity by averaging all pixels that belong to the same white matter structure (Figure 3). The results were similar to those by VBA, but abnormal areas with statistical significance extended to the frontal lobe white matter, the cingulum, the thalamus, the cortex, and the cotralateral cerebellum. While FA was decreased in the abnormal white matter regions, many gray matter structures, including the cortex far from surgical area, lenticular nucleus, and caudate had increased FA, which might represent reduction of the complexity of axonal architectures in these regions. One unexpected finding is the unchanged FA in the corona radiata regions where the corpus callosum and projection fibers are merged and FA is typically low. We hypothesized increased FA in these regions because of the lack of the commissural tracts and less "mixing fibers". However, our study didn't observe increased FA, challenging the current notion of "fiber mixing areas" of these low FA regions in the corona radiata.

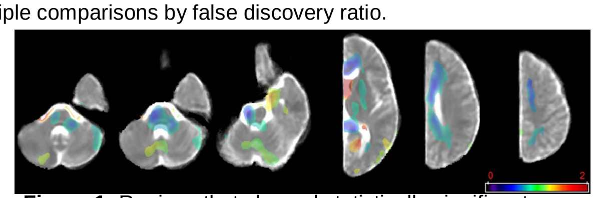

Figure 1: Regions that showed statistically significant differences in relative size according VBA. Colors represent the ratio hemispherectomy subjects / controls. Red indicates enlargement and blue indicates shrinkage.

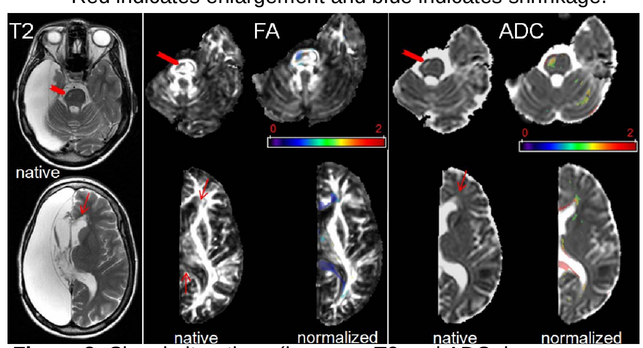

Figure 2: Signal alterations (hyper on T2 and ADC, hypo on FA) in CST (thick arrows) and corpus callosum (narrow arrows) detected in VBA. Color code is the same as in figure 1.

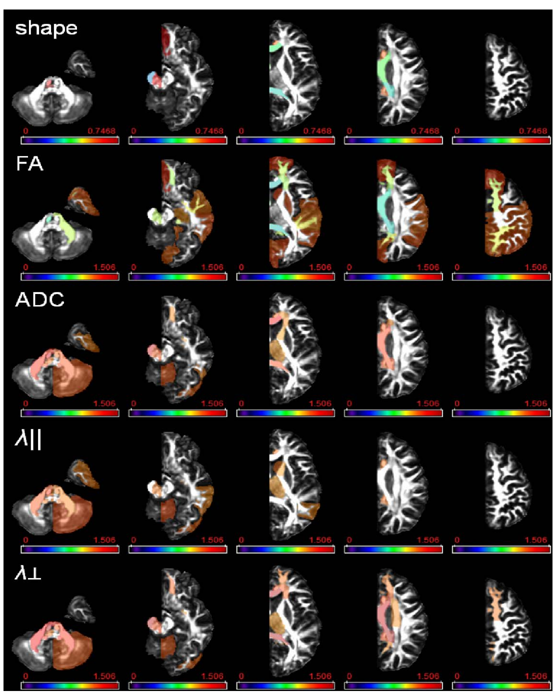

Figure 3: Regions that showed statistically significant differences in relative size and diffusivity measurements according Atlas-based analysis. Colors represent the ratio hemispherectomy subjects/controls.

***CONCLUSION*:** The normalization-based study of hemispherectomy patients clearly identified Wallerian degeneration of the white matter. The study also detected increased FA in the gray matter structures. Unexpected results included the lack of FA abnormalities in the medial lemniscii and "fiber mixing areas" in the corona radiata.

***BIBLIOGRAPHY*:** Pierpaoli C, et al. NeuroImage, 2001; 13:1174–1185; Miller MI et al. Proc Natl Acad Sci U S A. 2005,102(27):9685-90; Wakamoto H et al. J Child Neurol. 2006;21(7):566-71; Concha L, et al. Epilepsia 2007; 48(5):931–940; McMillan AB, et al. Neuroimage 2004;23(1):167-74; Oishi K et al, Neuroimage 2008 (submitted).

This study was supported by NIH grants F05NS059230 (AVF), P41RR015241 (PVZ), AG20012 and RR015241 (SM).