Cortical thickness is correlated with tract-specific fractional anisotropy in Type I Diabetes

D. T. Franc[1], C. Kodl[2], B. Mueller[2], R. Muetzel[2], E. Seaquist[2], and K. O. Lim[2]
[1]University of Minnesota, Minneapolis, Minnesota, United States, [2]University of Minnesota

Introduction The deleterious effects of diabetes mellitus on the retina, renal, cardiovascular, and peripheral nervous systems are widely acknowledged. Less attention has been given to the effect of Type 1 diabetes on cognitive function and brain structure. However, there is recent evidence that longstanding disease may have a subtle effect on cognition, affecting certain brain processing tasks (1). Additionally, local white matter lesions have been identified in patients with Type 1 diabetes (2), and mild brain atrophy has been observed previously (3). This study uses cortical thickness measurements from structural MRI and white matter tract measures from diffusion tensor imaging (DTI) to investigate gray and white matter changes in subjects with longstanding Type 1 diabetes.

Methods 25 subjects with diabetes mellitus for at least 15 years and 25 healthy controls matched by age and gender were identified. At the time of the study, blood glucose levels were taken from subjects from the diabetes group, and the MRI was performed if blood glucose levels were measured to be between 100-250 mg/dl. No gross abnormal findings were observed in routine structural MRI.

DTI Axial DTI was performed using the following parameters: The field of view was positioned to cover the entire cerebrum. Acquisition parameters for the dual spin echo, single shot, echo planar, diffusion weighted sequence are: TR=8000msec, TE=83msec, 128x128, 32cm FOV, 2mm skip 0, 64 slices, b value=1000. Diffusion was measured along 12 non-collinear directions as follows: (Gx,Gy,Gz) = {[1.0,0.0,0.5], [0.0,0.5,1.0], [0.5,1.0,0.0], [1.0,0.5,0.0], [0.0,1.0,0.5], [0.5,0.0,1.0], [1.0, 0.0,-0.5], [0.0,-0.5, 1.0], [-0.5, 1.0, 0.0], [1.0,-0.5, 0.0], [0.0, 1.0,-0.5], [-0.5, 0.0, 1.0]}. DTI pre-processing was performed using the FMRIB Software Library (FSL). Eddy-corrected and dewarped fractional anisotropy (FA) maps were processed using FSL's Tract-Based Structural Statistics program (4), and skeletonized FA maps representing the major white matter tracts for each subject were produced. Tract-specific regions-of-interest (genu of corpus callosum, anterior body of corpus callosum, posterior body of corpus callosum, splenium of corpus callosum, occipital lobe/optic radiations, superior cingulum bundle, posterior corona radiata, anterior corona radiata, superior longitudinal fasciculus, forceps minor) were then generated using primary eigenvector maps and structural images to determine the anatomic regions through which these skeletonized tracts pass. Figure 1 demonstrates the posterior corona radiata (left) and occipital/optic radiation tract-specific ROIs (all in red) overlaying the FA skeleton and map. Groupwise statistics were calculated for the average FA values for these tract-specific ROIs.

Volumetric analysis A 3D T1 MPRAGE sequence was acquired with the following parameters: TR=2530ms, TE=3.63ms,TI=1100ms, 1mm isotropic, FOV=256, 256x256 matrix. Cortical thickness measurements were made from the T1 image using the Freesurfer 4.0 software package (5) and used to determine an average cortical thickness for each lobe bilaterally.

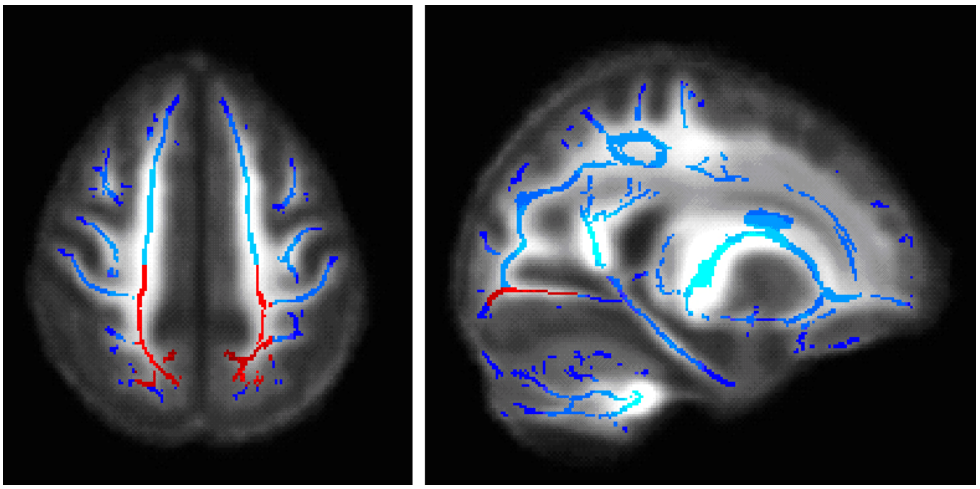

Figure 1: Posterior corona radiata (left) and occipital tract-specific ROIs

Results Average FA values in the skeletonized white matter tract ROIs were found to be significantly lower for the Type 1 diabetes group in occipital ($p = .001$, Cohen's effect size $d = -.823$), posterior corona radiata ($p = .001$, $d = -.407$) and splenium ($p = .040$, $d = -.533$) ROIs. Average cortical thickness was found to be significantly lower in the diabetic group in the occipital lobe bilaterally ($p = .022$, $d = -.790$). When correlation analyses were performed across all subjects, the occipital lobe cortical thickness was found to be correlated with average FA in the occipital/optic radiations tract (Pearson's $R = .484$, $p = .000$), posterior corona radiata ($R = .379$, $p = .007$) and forceps minor ($R = .412$, $p = .003$). When additional correlation analyses were performed between cortical thickness for the other lobes and associated white matter tracts, the frontal lobe average cortical thickness was correlated with average FA in the forceps minor ($R = .394$, $p = .005$). The parietal lobe average cortical thickness was correlated with average FA in the superior longitudinal fasciculus ($R = .383$, $p = .006$).

Discussion A posterior predominance for deficits in both cortical thickness and FA in a diabetic population was observed in this study. Additionally, correlations between cortical thickness and FA within associated tracts were found in the occipital, parietal and frontal lobes. This study presents a method for calculating tract-specific DTI measures while minimizing the partial volume effects inherent in fiber tracking and voxel-based approaches.

References

1. Brands AM, et al. Diabetes,55,1800-6, 2006.
2. Brands AM, et al. Dement Geriatr Cogn Disord, 23, 343-50, 2007.
3. Lobnig BM, et al. Diabet Med, 23, 32-9, 2006.
4. Smith SM, et al. Neuroimage, 31, 1487-505, 2006.
5. Fischl B and Dale AM. PNAS, 97, 11044-11049, 2000.

Acknowledgements This work was supported by BTRR - P41 RR008079 and P30 NS057091.