White-Matter Microstructure Differences Between Cochlear Implant Candidates and Their Hearing Peers: A Pilot Diffusion Tensor Imaging Study

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Introduction

- Presbycusis occurs in one in three people in the United States between the ages of 65 and 74 [1]. Sensory degradation/deprivation due to hearing loss (HL) can result in significant changes in gray and white matter of the brain [2,3].
- The cochlear implantation surgery is one of the primary treatments for individuals with severe HL. This poster determines the differences in white matter microstructure between a group of individuals who have severe to profound HL and are qualified to receive the cochlear implant (CI) and their age-/sexr-matched hearing peers using Diffusion Tensor Imaging (DTI).
- This poster presents preliminary findings from an ongoing work in the Neuroimaging for Language, Literacy and Learning (NL3) lab.

Materials and Methods

- Participants: A total of 12 right-handed native English speakers (six men, CI candidate group mean age: 67.9 $\pm$ 11.2, Comparison group mean age: 66.2 $\pm$ 7.0). CI group has 6 participants with severe sensorineural hearing loss (5 bilateral, 1 unilateral right-side HL) who were considering undergoing CI surgery (range of duration of deafness: 3 to 40 years). The comparison group has 6 are age- and sex-matched hearing peers.
- Procedure: Diffusion Weighted Imaging (DWI) data were collected using Siemens Skyra 3T MRI with 32-head coils. The scan involved both anatomical MRI data and DWI data. During their visit, participants also completed demographics questionnaires,and the Kaufman Brief Intelligence Test. Pure tone audiometry test was also administered to evaluate whether the comparison group has HL using Kuduwave Pro TMP device.
- DWI Preprocessing: First, DCM files were converted to NRRD file using 3DSlicer. Second, the volumes with high artifacts were identified using DTIPrep and were removed for quality control after visual inspection. Third, Topup procedure was used to correct for field distortions in the data due to local magnetic field inhomogeneity. Then, Eddy current correction was done with Topup parameters using FSL command eddy.
- DTI Fitting: Preprocessed DWI data were then fitted using tensor modeling (FSL dtifit command). Fractional anisotropy (FA) maps were generated for each participant.
- Group Analysis: To minimize the inter-subject variability in white matter tracts for group analysis, all images are aligned into a target space and a skeleton of white matter tracts (green) in Figure 1 is created from the average of all participants using Tract-based spatial statistics (TBSS) [4.] All subjects' FA images were aligned into a template of averaged FA images (FMRIB-58) in Montreal Neurological Institute (MNI) space using a non-linear registration algorithm implemented in FNIRT (FMRIB's Non-linear Registration Tool) [5]. Each subject's normalized FA image was then projected onto the mean FA skeleton by filling the mean FA skeleton with FA values from the nearest relevant tract center, which was achieved by searching perpendicular to the local skeleton structure for maximum value. This second local coregistration step can alleviate the alignment problems. Voxel-wise statistical analysis across subjects on the skeleton space was carried out for voxels with FA > 0.2 to include only major fiber bundles and exclude peripheral tracts with significant inter-subject variability.
- Statistical Analysis: For the voxel-wise analysis, a permutation program "Randomise" in FSL was used to produce two-sample t-test map. The resulting contrast maps were enhanced via Threshold-Free Cluster Enhancement (TFCE) ($p < .05$).

Results

- TFCE-corrected results: We found significantly higher Fractional Anisotropy (FA) values in the anterior corona radiata (ACR) in the comparison group of age- and sex-matched hearing peers than the CI candidate group (see Figure 1). FA quantifies the white matter microstructure. Higher FA typically indicate greater white matter integrity and more organized fiber pathways, while lower FA values may indicate damage or disruption to white matter tracts. ACR is part of the limbic-thalamo-cortical circuitry and includes thalamic projections from the internal capsule to the prefrontal cortex. ACR transmits auditory information to and from the cerebral cortex in the central auditory pathway.

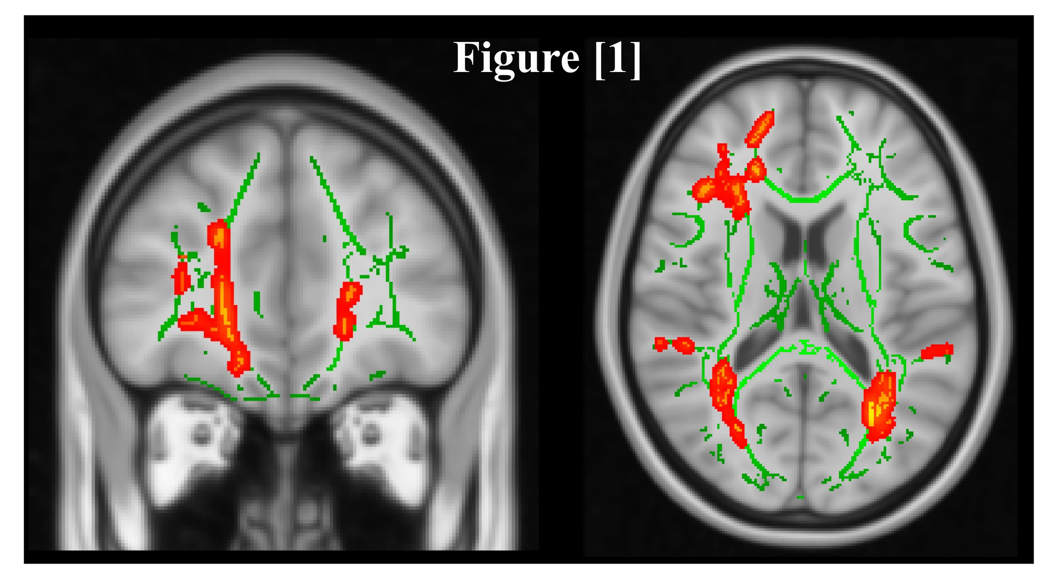

Figure 1 shows the FA values that were larger in the control group than CI candidate group (TFCE corrected p<.05). The bilateral ACR in red-orange superimposed on the fiber skeleton (Green) and overlaid on the FMRIB FA template. Images are in radiological convention. Left is the participant's right and right is the participant's left.

In Figure 2, FA difference in the ILF is identified. ILF connects the temporal and occipital lobes [6]. Our finding supports previous finding that the ILF may be associated with the integration of information between speech and auditory regions of the auditory cortex [7].

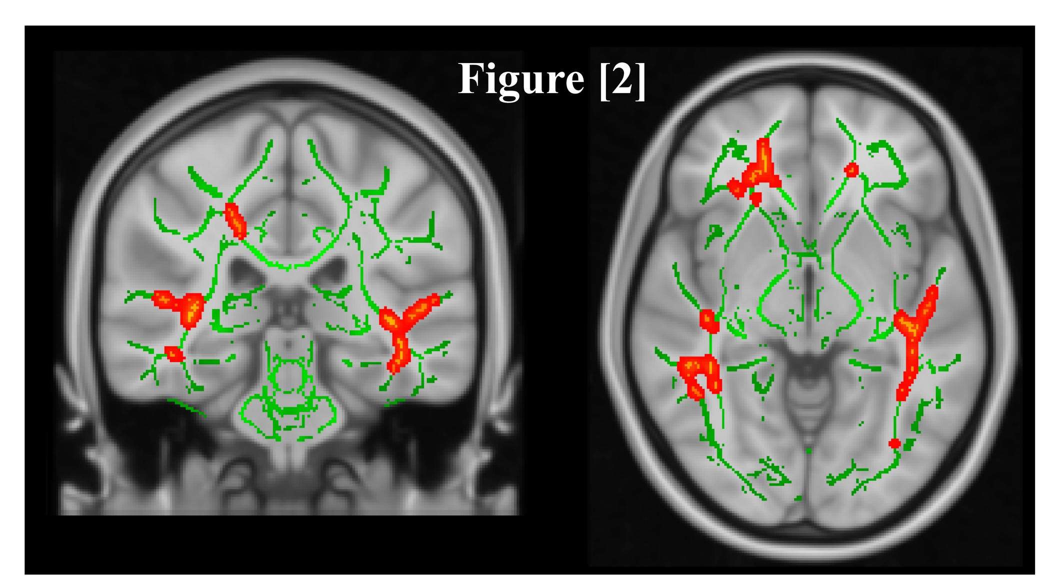

Figure 2 shows the left inferior longitudinal fasciculus (ILF). Images are in radiological convention. Left is the participant's right and right is the participant's left.

No areas of the brain showed higher FA for CI candidate group compared to their hearing peers.

Conclusion

Our results indicate that white-matter microstructure is a sensitive measure to detect changes in structural changes due to HL in the brain. The data collection for this work is still ongoing. One aim of this ongoing research is to investigate the potential use of DTI as a pre-implantation evaluation tool to improve the prognosis for CI candidates.

Ultimately, this work may provide empirical evidence on guiding the development of an innovative pre-surgical intervention that has the power to increase white matter microstructure in specific brain regions before surgery. This novel pre-surgical intervention can be used to prepare the CI candidate's brain to adapt to CI devices better.

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