Delineation of Subcortical Language Pathways by DTI Fiber Tracking and Cortical Stimulation Mapping

S. Chung[1], M. S. Berger[2], J. I. Berman[1], M. L. Gorno-Tempini[3], R. G. Henry[1]

[1]Radiology, UC San Francisco, San Francisco, CA, United States, [2]Neurosurgery, UC San Francisco, San Francisco, CA, United States, [3]Neurology, UC San Francisco, San Francisco, CA, United States

Introduction: Knowledge about neuronal connectivity between functional cortical centers is crucial for understanding how the brain works. Diffusion tensor Imaging (DTI) fiber tracking offers a unique opportunity to explore the subcortical white matter connection between cortical language centers non-invasively [1]. Prior attempts of delineating tracks related to language function using DTI fiber tracking did not show explicit connection between cortical regions, especially between frontal and parietotemporal lobe, or correlation with functional aspect of language. The purpose of this study is to show the connection between cortical language areas using DTI fiber tracking, and validate the tracks by comparing them with the intraoperative cortical stimulation mapping.

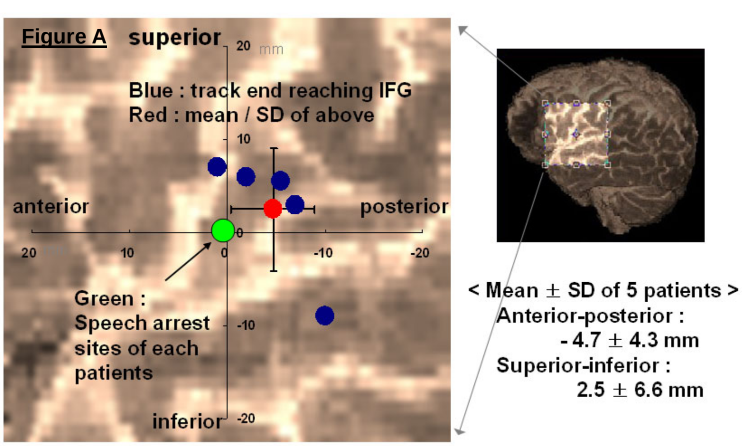
Methods: Thirteen subjects, six right-handed healthy volunteers and seven right-handed patients undergoing surgery for glioma located in the left perisylvian region, were selected. DTI was acquired with a single-shot multislice echo planar sequence and TR/TE=6 s/100 ms, 6-9 NEX, pixel size 1.7x1.7 mm^2, slice thickness 2-3 mm. Diffusion gradients were applied in 6 non-colinear directions with b=1000 s/mm^2 in addition to b=0 s/mm^2 image. In brain tumor patients, intraoperative awake cortical stimulation mapping was also performed and speech arrest sites were localized with the stereotactic surgical navigation system.

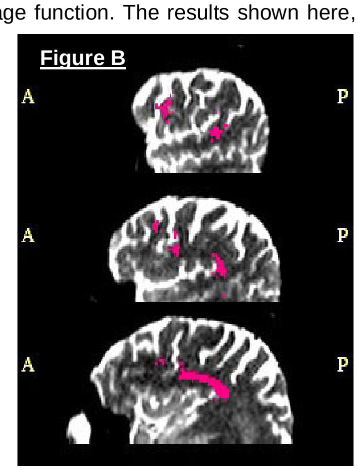
Fiber tracking was done using in-house software based on the FACT [2] algorithm, which follows the primary eigenvector from voxel to voxel in 3D space. First, tracks were launched from a starting region encompassing a coronal slice of the arcuate fasciculus, which was determined in the anisotropy map, and the resulting tracks were further filtered to remove tracks not reaching the cortices of interest. In tumor patients, speech arrest cortical sites were compared with the locations of tracks connecting frontal and temporal lobes.

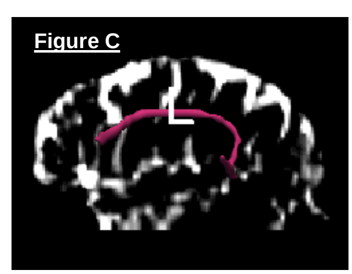
Results: Tracks launched from the arcuate fasciculus had a consistent pattern in all normal controls having three major connections; between inferior frontal gyrus (IFG) and supramarginal gyrus (SMG), IFG and posterior superior temporal gyrus (PSTG), IFG and posterior middle temporal gyrus (PMTG). Connection between IFG and PSTG was relatively weak compared to the other two, and this connection was not found in one left hemisphere and two right hemispheres. No gross asymmetry in the connection pattern between left and right side of the brain was observed. The end points of tracks reaching IFG were mainly located around the inferior precentral sulcus, which corresponds to Brodmann area 6 and 44. In tumor patients, the pattern of connections was similar, though the likelihood of having these connections were less than in normal controls; five out of seven had connections IFG to SMG, and IFG to PMTG, and two patients had connection IFG to PSTG. Track end points in the IFG connecting temporal lobe were closely located to speech arrest sites, all within 10 mm boundary from the speech arrest site (Fig. A)

Discussion/Conclusion: In this study, it was shown that DTI fiber tracking can be used to understand the structures related to language, based upon the assumption that arcuate fasciculus plays an important role in the connection. From the study of normal controls, fiber tracking was proved to be a reliable tool, generating similar fiber track patterns in all normal subjects. However, since fiber tracking itself does not reveal the function of pathways, comparison to the cortical stimulation mapping was performed in order to validate the tracks. Considering that the effective radius of cortical stimulation is 5 to 10 mm [3], and that errors arise during stereotactic registration, speech arrest sites and the track end points in the IFG can be said to be closely located to each other, giving credibility to the DTI fiber tracking as a tool to investigate the connectivity of language function. The results shown here, especially the fact that IFG was strongly connected to SMG as well as temporal lobe, are also supported by other studies of language such as cortico-cortical evoked potential study [4] and intraoperative subcortical stimulation study [5]. In conclusion, DTI fiber tracking is an effective, non-invasive tool to investigate neuronal connectivity of language functions.

Figure A: Diagram showing the relative location of tracks reaching inferior frontal gyrus and speech arrest sites in five brain tumor patients. **Figure B:** sagittal section images of left side of a normal control brain overlayed with the tracks representing arcuate fasciculus connecting inferior frontal gyrus and posterior superior temporal gyrus. **Figure C:** 3D rendering of the tracks shown on Figure B.







Reference:
[1] Henry, R., et al. Neuroimage, 21(2):616-622
[2] Mori, S., et al. Ann. Neurol., 45: 265-269
[3] Haglund, MM et al. J. Neurosurg., 78:785-793
[4] Matsumoto, R., et al. Brain, 127, 2316-2330
[5] Duffau, H. et al. Brain, 125, 199-214

Funding from NIH/NCI CA10033