MRI Microscopy of Human Motor Neurons Progress Report

Deacon, T. (University of Califronia, Berkeley, Anthropology); Niederhut, D. (University of Califronia, Berkeley, Anthropology); Mareci, T. (UF, Biochemistry and Molecular Biology); Zeng, H. (UF, MBI); Perez, L. (UF, MBI)

Introduction

A key feature of human behavior is spoken language, but the neural structures that permit humans to learn vocal culture while other apes cannot have yet to be described. A popular hypothesis is that humans have evolved a direct corticobulbar connection originating from the frontal lobes and ending in the nucleus ambiguus, the hindbrain motor nucleus that controls the intralaryngeal muscles (Jürgens, 2002). It is further hypothesized that this direct connection allows for more fine control of this structure, in a manner analogous to the way direct frontal innervation of spinal motor nuclei allows for fine motor control of the hands in apes. While there is not conclusive evidence that this ambiguo-frontal tract exists, it's potential existence has been reported in the literature for so long that it is now often cited as a conclusion, and not as a possibility. We propose to use high-field, diffusion weighted MRI to establish the existence, or nonexistence, of this hypothesized connection.

Experimental

Structural and diffusion weighted images were acquired on the Agilent 11T MRI, using the 120HD gradient set. Two sets of diffusion-weighted images were acquired, one at 250um isotropic, and one at 200um isotropic, both with 32 directions. Directional volumes were aligned using ITK-SNAP, and diffusion parameters were modeled using FSL's BEDPOSTX utility (Behrens, Johansen-Berg, Jbabdi, Rushworth, & Woolrich, 2007). Seed masks for tractography were drawn by hand following Nolte (2009) on structural images for the nucleus ambiguous, with the pyramidal tract, spinal trigeminal tract, and solitary tract as controls. Probabilistic tractography was computed with FSL's PROBTRACK function, with seed masks transformed into diffusion space via coregistration (Jenkinson & Smith, 2001; Smith et al., 2004).

Results and Discussion

Seed masks drawn on the corticospinal, spinothalamic, and solitary tract at the level of the lower pons successfully reproduce the known major pathways of these tracts. However, they do not produce any traces terminating in locations outside their own cell columns after thresholding is applied. The mask drawn over the nucleus ambiguus likewise did not produce any traces that left this nucleus, after thresholding. Tractography for the pyramidal tracts was unable to resolve crossing fibers in the medullary decussation, which had previously been demonstrated at a similar resolution (Aggarwal et al., 2013). It is possible that higher resolution images will be needed to test the corticobulbar hypothesis directly.

Conclusions

DWI acquired at 200um successfully recreates known tracts through the extent of the lower pons and medulla. The fact that images at this resolution were unable to produce tracts leaving any hindbrain nuclei suggests that this resolution is not sufficient to detect a ambiguo-frontal connection, should one exist. As it is unlikely that the 11T system will be able to push image resolution for diffusion scans below 200um, we plan to try a similar protocol using the Avance III 750MHz system. To the best of our knowledge, this will be the first study to test questions about human neuroanatomy at this field strength, 17.6T.

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