Improved in-vivo reconstruction of the auditory pathway using high spatial resolution diffusion MRI

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Audience: Scientists interested in the auditory system and reconstruction of its pathways from diffusion MRI.

Purpose: The ascending central auditory pathway begins as the axons of the primary auditory afferents enter the brainstem at the pontomedullary junction, synapsing at the cochlear nuclei. From there, fibers ascend towards the inferior colliculus (IC) via the superior olivary complex and lateral lemniscus. Neurons of the inferior colliculus synapse at the medial geniculate body (MGB) and the final axons of the pathway form the auditory radiation and end at the auditory cortex (AC). While the IC and MGB can readily be identified with MRI, the complex system of auditory tracts has been difficult to identify due to their relative small size (MGB: ~90 mm^3; superior olive: ~20 mm^3)[1,2] and proximity to many major crossing fiber tracts such as the optic radiations. The auditory radiations have been characterized in the past using diffusion tensor imaging (DTI) probabilistic tractography[3], and both the auditory radiations and colliculogeniculate pathway were identified using a combination of DTI and functional MRI[4]. However these tractographies are unsuccessful in many subjects and subcollicular auditory pathways have yet to be identified using these methods. We compared high-resolution 3 tesla (3T) and 7 tesla (7T) diffusion MRI data from the Human Connectome Project (HCP)[5,6] using probabilistic tractography to look for reductions in spurious connections and improvements in central auditory pathway characterization. We hypothesized that, for small white matter pathways such as the auditory tract, the unique spatial resolution achieved at 7T (70% smaller voxel volume than 3T) will lead to a better delineation of these tracts.

Methods: Two subjects from the HCP database were analyzed. HCP 3T data was acquired with a 1.25mm^3 voxel size, at 3 *b*-values (1000, 2000 and 3000 s/mm^2) with 90 directions per *b*-value[5]. HCP 7T data was acquired with a 1.05mm^3 voxel size, at 2 *b*-values (1000 and 2000 s/mm^2) with 65 directions per *b*-value[6]. Diffusion MRI data was analyzed by probabilistic tractography using FSL[7]. T1-weighted structural data (0.7mm^3 voxel size) was registered to MNI152 space and Jülich probabilistic histological atlas for identification of TE1.0 (primary auditory cortex)[8] with additional manual segmentation to confine the ROI to the Heschl's gyrus, which was used as a seed. Inferior colliculi and medial geniculate bodies were identified and segmented manually and used as waypoints.

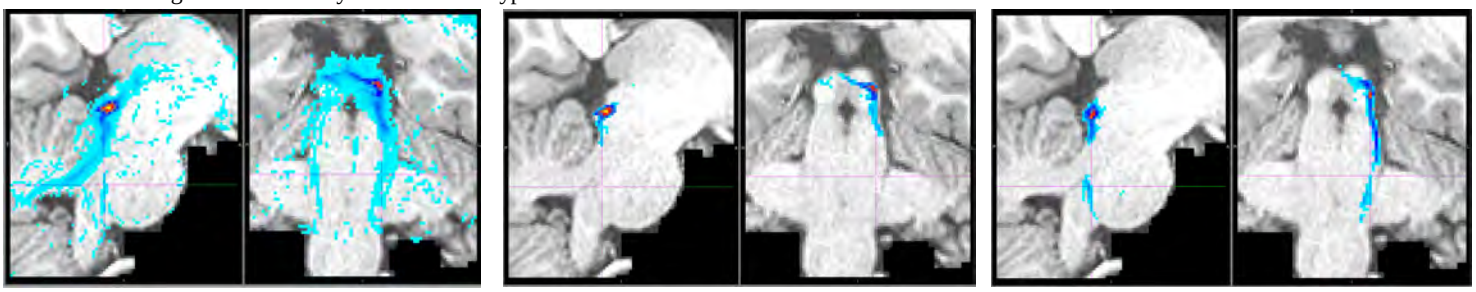

Figure 1 Sagittal and coronal slices of subcollicular auditory pathway in same subject with tractographies performed on 3T data (left: low threshold, middle: high threshold) and 7T data (right). Thresholding to eliminate spurious pathways with 3T tractography also eliminates subcollicular pathways that remain preserved with 7T imagaing.

Results and Discussion: Auditory radiations and colliculogeniculate pathways were identified in both subjects bilaterally at 3T and 7T. In 7T tractographies an ipsilateral subcollicular pathway was clearly characterized in both subjects bilaterally likely representing the lateral lemniscus. This pathway terminated near the pontomedullary junction. It was less prominent but visible with 3T tractographies in both subjects bilaterally. Higher thresholds, needed to eliminate more prominent spurious connections present in the 3T dataset when compared to 7T (e.g. cerebellum, and non-auditory cortical areas), also eliminated any observed subcollicular pathways in 3T tractographies (Fig. 1).

Conclusion: This is the first study to identify subcollicular auditory pathways using high spatial resolution diffusion MRI. It illustrates how such data can improve identification of fine white-matter tracts that intersect other fibers. A better understanding of central auditory system anatomy in vivo may have applications in the evaluation of medical conditions such as hearing loss and tinnitus.

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