HARDI Fiber Tracking is Necessary to Delineate the Auditory Radiation

J. I. Berman[1,2], and T. P. Roberts[1,2]
[1]Radiology, Children's Hospital of Philadelphia, Philadelphia, PA, United States, [2]Radiology, University of Pennsylvania, Philadelphia, PA, United States

Introduction: The auditory radiation connects the thalamus to the auditory cortex and is necessary for hearing and language comprehension. Recent studies of autistic children have detected delayed auditory evoked responses that may be connected to structural abnormalities [1]. Diffusion MR is sensitive to changes in white matter architecture; however, the diffusion tensor model can not accurately depict the auditory radiation as it crosses the inferior longitudinal fasciculus (ILF). It is necessary to develop robust methods of delineating the entire auditory radiation for quantitative population studies. This work demonstrates the consistent ability of high angular resolution diffusion imaging (HARDI) fiber tracking to delineate the full length of the auditory radiation in a population of children.

Methods: Diffusion MR was acquired from 6 children with autism spectrum disorder aged 8 to 14 years and 3 control children aged 9 to 13 years on a 3T Siemens scanner. The whole-brain HARDI acquisition included 64 gradient directions at b=3000 s/mm^2, TR/TE=16.9s/106ms, voxel size=2x2x2mm. An additional standard DTI acquisition included 30 gradient directions at b=1000 s/mm^2, TR/TE= 14s/75ms, and voxel size 2x2x2mm. The solid angle q-ball reconstruction was used with a probabilistic HARDI fiber tracking algorithm [2,3]. For comparison, DTI fiber tracking was performed with both the HARDI acquisition and the standard DTI acquisition. Both DTI fiber tracking trials were performed with a deterministic algorithm based upon FACT [4]. Fiber tracks were launched from a region of interest manually drawn in the white matter of Heschl's gyrus and targeted to a region of interest on the inferior thalamic surface generated from the Harvard-Oxford atlas [5]. Regions of interest were initially placed on images from the HARDI acquisition and aligned to the standard DTI volume using FLIRT [6]. HARDI and DTI fiber tracking were performed with an FA threshold of 0.125, an angle threshold of 70°, and 128 starting points per voxel. Successful fiber tracking was defined as the presence of at least one trajectory connecting Heschl's gyrus to the medial geniculate nucleus along an anatomically plausible route. Left and right side auditory radiations were examined separately.

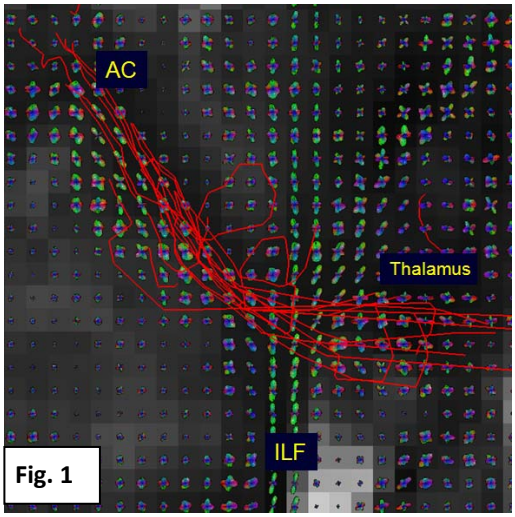

Fig. 1

Results: Figure 1 shows an example set of HARDI fiber tracks (red streamlines) crossing the ILF and connecting the auditory cortex (AC) with the thalamus. The q-ball orientation density functions show the crossing anterior-posterior ILF (green peaks) and the smaller left-right peaks representing the auditory radiation.

HARDI fiber tracking successfully delineated the auditory radiation at a significantly higher rate than both DTI fiber tracking methods (Fisher's exact test, P<0.005). As seen in the table, HARDI was successful in all cases. The success rate of 30-direction and 64-direction DTI fiber tracking were not significantly different from each other. Figure 2 shows HARDI and 30-direction DTI results from all 9 subjects.

	Successful	Unsuccessful
DTI – 30 Directions	8	10
DTI – 64 Directions	6	12
HARDI – 64 Directions	18	0

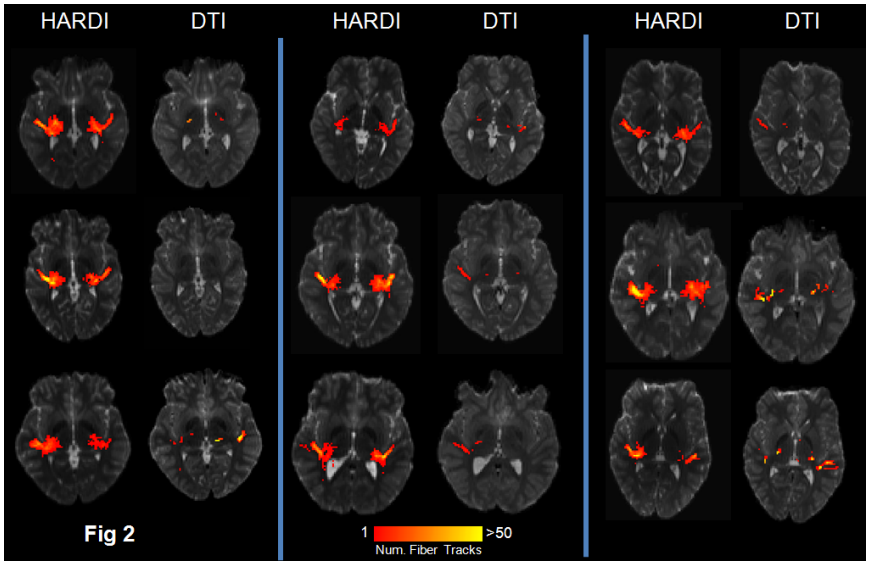

Fig 2

Discussion: This work provides the framework for quantitative studies of the auditory system in children with autism or language impairments. The DTI cases classified as successful often contained very few fiber trajectories which did not accurately delineate the entire volume of the acoustic radiation. DTI fiber tracks tended to emerge from Heschl's gyrus and incorrectly follow the dominant anterior-posterior coursing ILF. HARDI data can reliably delineate the entire auditory radiation and enables tract-specific measurements not feasible with standard DTI techniques.

References:
1) Roberts, TPL, et. al, Autism Research, 2010, 3.
2) Aganj, I. et. al., MRM 2010. 64:2
3) Berman, JI. et. al., Neuroimage 2008. 39:1
4) Mori, S., et. al., Ann. Neurol. 1999; 45.
5) Desikan, RS, et. al, Neuroimage. 2006: 31.
6) Jenkinson, M., et.al., Med. Image Analysis. 2001. 5(2)