DIFFUSION TENSOR IMAGING TRACTOGRAPHY USING FLUID-ATTENUATED INVERSION RECOVERY

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INTRODUCTION: Partial volume averaging from fast and isotropically diffusing Cerebro-Spinal Fluid (CSF) results in a significant decrease in the fractional anisotropy (FA) of tissues adjacent to CSF spaces. The use of fluid-attenuated inversion recovery (FLAIR) to suppress the CSF signal prior to a typical Diffusion Tensor Imaging (DTI) sequence has been shown to reduce this artifact [1] and to increase the FA values of specific tissues by about 10% [2]. Most tractography algorithms depend on FA thresholds and principal eigenvectors in order to determine tract continuation [3, 4]. Therefore, reduction of tissue FA values by partial volume averaging with CSF may cause the tractography algorithm to exclude potential voxels and omit or prematurely terminate tracts. The fornix, the main efferent of the hippocampus, was chosen to assess the role of CSF suppression in the accurate extraction of fibers since it is surrounded by CSF in most of its trajectory, especially at the levels of the crura, body and columns. The purpose of this study was to compare the effectiveness of fiber extraction between standard DTI and FLAIR DTI tractography.

MATERIALS AND METHODS: Five healthy volunteers (ages 26 to 35) were scanned with a 1.5T Siemens Sonata. Standard DTI parameters were: 63 axial slices, 2 mm thickness with no inter-slice gap, TR=10 s, TE=88 ms, FOV=256x256 mm, image matrix=128x128 (interpolated to 256x256), 6 diffusion directions, b=1000 s/mm^2, 8 averages, scan time=9:30 min. FLAIR DTI parameters were the same except for the acquisition of only 26 slices (exact same slices as the standard DTI central slices) and the added inversion RF pulse with a TI of 2200 ms (scan time=8:23 min). The images were then transferred to a PC running DTIstudio (Johns Hopkins University), which uses the FACT algorithm described by Mori et al [3]. We used the following parameters for fiber tracking: start if FA>0.3, stop if FA<0.3, stop if angle>70°. A Region of Interest (ROI) for fiber selection was drawn on the FA maps derived from the FLAIR DTI datasets around the columns of the fornix to generate the initial set of fibers passing through this region, then a second ROI was drawn in a coronal orientation at the level of the fusion of the crura; only the fibers that passed through both ROIs were retained. The same two ROIs were then superimposed on the standard DTI FA maps. Rogue fibers (those that are clearly not part of the fornix) were manually deleted. The extracted fibers were exported to Amira (TGS Inc.), where the number of fibers was counted for each technique.

RESULTS AND DISCUSSION: The signal-to-noise ratio (SNR) was 33±2 and 25±1 for the b=1000 s/mm^2 images from standard DTI and FLAIR DTI, respectively. Despite the 24% decrease in SNR due to FLAIR, the resultant SNR was sufficient for performing tractography. Qualitatively, the fornix appeared thicker on the FLAIR DTI derived tracts than those extracted from standard DTI. An increase of 50% in the number of fibers extracted from the FLAIR DTI datasets was observed as compared to standard DTI (Table 1). The algorithm working on the standard DTI datasets was not able to continue beyond the crura in all five subjects, and in only one it was able to reach the septal region, whereas the tracts extended to the hippocampus in five of ten crura and to the septal region in four of the five subjects when FLAIR DTI was used (Figure 1). The abrupt end of the fornix at the crura is due to the presence of many voxels in this region with an FA value below threshold for fiber tracking (0.3 in this case) in the FA maps obtained from standard DTI. Nevertheless, it is more common to obtain anatomically inconsistent fibers from FLAIR DTI with FACT, perhaps due to the proximity of the crura to the corpus callosum from where the rogue fibers can spread to other regions of the brain and also due to the lower SNR in the FLAIR DTI datasets; however, these anatomically inconsistent fibers can be easily trimmed after depiction. In conclusion, the use of FLAIR DTI to suppress contaminating signal from CSF results in an increase in the number of fibers extracted by FACT from a white matter tract such as the fornix.

	Fibers extracted from fornix		Ratio of fibers
Subject	**Standard DTI**	**FLAIR DTI**	**FLAIR/Standard DTI**
1	188	260	1.4
2	85	126	1.5
3	97	132	1.4
4	144	197	1.4
5	81	148	1.8
Average	**119**	**173**	**1.5**
SD	**46**	**56**	**0.2**

Table 1. Number of fibers extracted from the fornix using Standard DTI and FLAIR DTI. FLAIR DTI yields 50% more fibers in the fornix relative to standard DTI **(p=0.001)**.

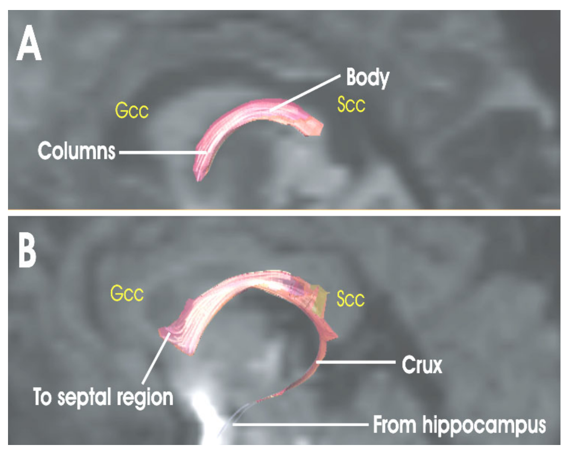

Figure 1. Left fornix from healthy volunteer. **A**: Extracted from standard DTI. **B**: Extracted from FLAIR DTI. The fibers reach the hippocampus in B, whereas they stop at the crux in A. Notice also the greater number of fibers ending in the septal region. For points of reference, **Gcc** and **Scc** are the genu and splenium of the corpus callosum, respectively.

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